

14 FM BUGS TO BUILD



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# 14 FM BUGS TO BUILD

by

Colin Mitchell

Learn the secrets and theory behind  
micro-power FM transmission



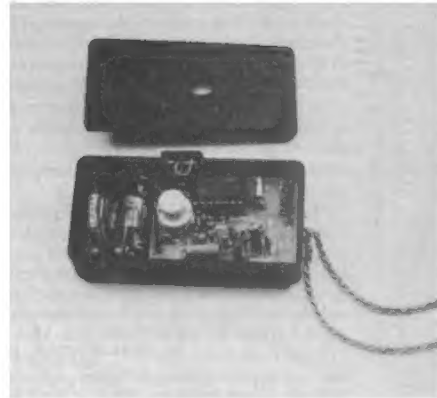
Our 600m Cube of Sugar Bug

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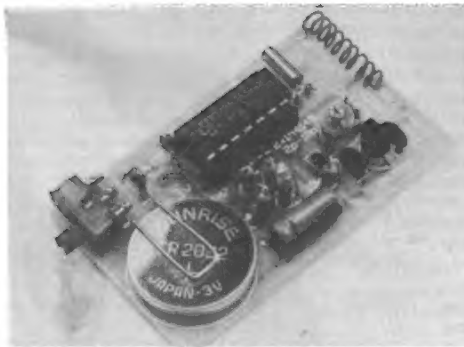
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# 14 FM BUGS TO BUILD

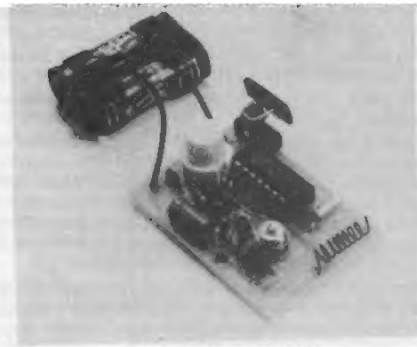
by  
**Colin Mitchell**



The 15m Minder can be worn around the neck for personal monitoring



15m Minder for a tic tac box



15m Minder for PP-12 box.  
see P. 5

**A Talking Electronics Publication**

# INTRODUCTION

In this issue we have presented 14 (and 2 extra) of our most popular FM bugs.

The first 2 projects are new, while the remainder have been taken from our first 3 FM bugs books: FM BUGS, MORE FM BUGS, and BUGGING AND ITS PREVENTION. The final project is also new and shows how we are constantly improving our designs to bring you the best possible.

One customer bought 4 FM bug kits from other kit-makers, while he was overseas. We put them together and none of them worked! They had actually left out one or two of the most important components, both in the kit and on the circuit diagram! I don't know how they ever expected the kit to work. Obviously nothing had been tested. When we go overseas we'll swamp the opposition! There's absolutely no competition. The projects in this issue have been tried and proven by over 30,000 successfully built kits and that's your guarantee of success.

The 3 FM bug books mentioned above are now out of print and to satisfy the stream of requests for back copies, we have decided to put all the bugs into one book.

This means you will miss out on some of the lesser articles, as we couldn't include everything.

This is one of the problems of producing such good projects. Even though some of our issues are up to 5 years old, nothing has gone out of date and the circuits are still the best available. We get lots of requests for the bugs and the prices have hardly risen in 5 years. It's always been our intention to produce kits at a competitive price and now that costs have risen all around us, our prices are better value than ever.

To get back to the topic: Many readers are very smart. They buy two copies of everything we produce. They use one in the workshop and keep the other in their library. They know the working copy will get a battering after months of use and have the clean copy to fall back on.

The one thing that's forbidden is to loan any of your copies. You will never get them back. We have had literally hundreds of readers request replacement copies after loaning a copy to a friend. The answer is always the same: "Oh, I loaned it to someone else and they haven't returned it!" or "Oh, I thought I returned it to you a long time ago. Gee, I don't know where it is now!" People are so dishonest - or maybe it's a reflection on the quality of the articles.

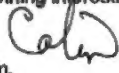
The answer is not to let anyone borrow. You can take it from me, you will never see it again - or the borrower!

This will be the last printing for "FM Bugs" etc so be warned! Look after your copy.

You will notice the projects have been presented in order of complexity, with the simple bugs at the beginning and working through to more complex designs. If you are just starting in this field, I suggest you build some of the simple circuits first and get to understand how they work. Each project adds a new feature to the design and you can see how the efficiency and range increases as you work through the book.

The projects introduce surface-mount technology as well as a grounding in miniaturisation. FM transmitters are so effective that they have become one of our most popular kits. Providing you don't increase the supply voltage above that specified, or transmit on top of a commercial radio station, you will not interfere with anyone else and you can use the bugs for all kinds of field work, picking up the sounds of the bush, talking between two parties or monitoring your own property.

I know you will have lots of fun so I'll leave it to you to pick out something interesting and clear a space on the workbench.

  
Colin.

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All the projects in this book as well as further copies of "14 FM Bugs to Build" are available from:

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Cheltenham, Victoria. 3192  
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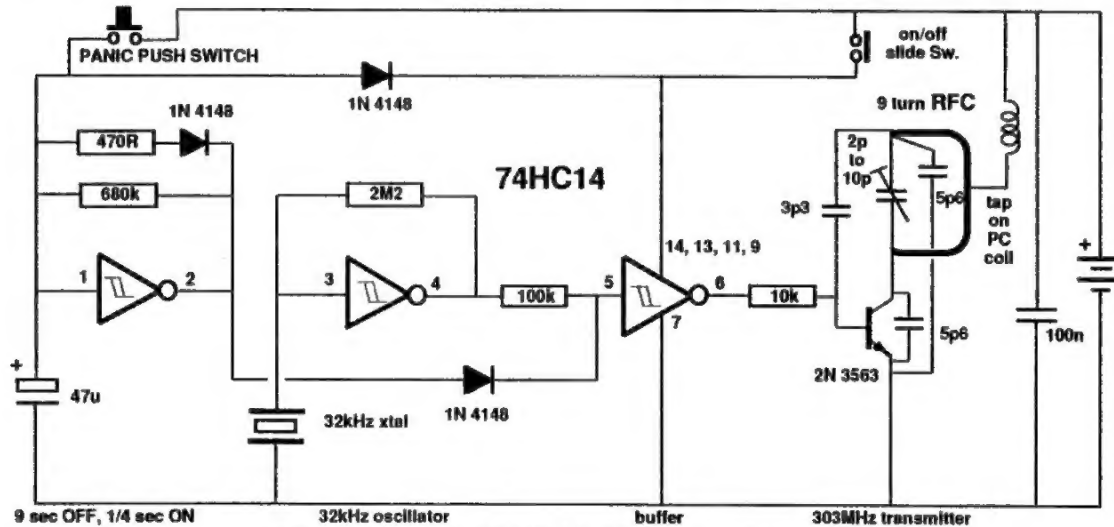
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# 15m MINDER

A person minder with 15 metre range

**Parts & 2 PC:**  
transmitter PC board or  
receiver PC board only  
You will also need th  
Meter to test the transmi

Fully built 15m Minders are available for \$120.00



## 15 METRE MINDER TRANSMITTER CIRCUIT

It resets the receiver every 9 seconds

Have you seen PANIC BUTTONS for the elderly? They are about the size of the cap of a pill bottle and generally placed around the neck or fitted to the wall near a toilet or shower.

When the button is pressed, a signal is transmitted to a nearby receiver to summon a nurse or relative.

This allows the patient to get immediate attention without having to call out and provides freedom to move around a house or nursing home.

The manufacturers of these systems claim a range of about 30 metres but when worn on the body the range is reduced to about 15 metres. The direction of the transmitter in relation to the receiver is also important and it is best to have it face the receiver.

But there's one hidden disadvantage with this type of set-up. The wearer does not know if he or she is within range of the receiver when an emergency call is made.

To overcome this problem we have designed a circuit that is constantly monitoring the transmitter so that if it gets out of range, the monitoring station is notified within about 25 seconds.

By providing this feature, the transmitter can be used for monitoring with 100% effectiveness. This is important where the patient has a tendency to move around, especially those who wander off

into the garden or street etc. If the receiver is placed at the front or back entrance of a building, the alarm will be triggered when the transmitter comes within a few metres and this will save calling out a search party!

The above situations actually describe two different systems - as you will see in a minute. Commercial panic alarms have one of these features but not both.

With our 15m Minder, you can change the operation from monitoring within a 15metre radius to monitoring when the transmitter enters the 15 metre field.

As with any system, where you are monitoring a life-saving situation, you must use it as a back-up ONLY and not rely on it to do the job totally. It must also be tested regularly to make sure everything is operating correctly.

### THE TRANSMITTER

The transmitter is designed to produce a short 32kHz tone every 9 seconds and this cancels a timing circuit in the receiver. If two of these resetting pulses are not received, the receiver considers the transmitter is out of range and activates the alarm.

A "panic button" on the transmitter overrides the monitoring situation and sounds the alarm when the button has been pressed for 2 seconds.

The transmitter circuit consists of 4 sections.

### TRANSMITTER PARTS LIST

- 1 - 470R
- 1 - 10k
- 1 - 100k
- 1 - 680k
- 1 - 2M2
- 1 - 3p3 ceramic
- 2 - 5p6 ceramics
- 1 - 100n ceramic
- 1 - 2p - 10p air trimmer
- 1 - 47u 16v electrolytic
- 1 - 32kHz watch crystal
- 3 - 1N 4148 signal diodes
- 1 - SPDT mini slide switch
- 1 - PC mount push button
- 1 - 9 turn RFC enamelled wire 3mm dia
- 1 - 74HC14 IC or 4584 - not 74c14
- 1 - 2N 3563 RF transistor
- 1 - 2 - 'N' cell battery holder
- 2 - 'N' cells
- 1 - 14 pin IC socket
- 5cm red and 5cm black hook-up wire
- 1 - 5 turn coil for Field Strength Meter
- 1 - PP-12 MINDER CASE
- 1 - 15m MINDER Transmitter PC board

trimmer cap

Starting from the left, we have a low-frequency oscillator. This consists of an inverter between pins 1 and 2 and a few passive components.

These components set the frequency



so that the output of the gate is HIGH for about 9 seconds and LOW for about 1/4 second. This uneven mark-space ratio is created by the 680k and 470R/diode combination. The 47u takes a long time to charge via the 680k resistor and input pin of the inverter is low for about 9 seconds. The output is high during this time and the gating diode prevents the signal from the second block reaching the buffer.

When the voltage on the 47u reaches 2/3 of rail voltage, the schmitt inverter changes state and the output goes low. This allows the tone to pass into the buffer and also the transmitter stage.

At the same time the 47u is rapidly discharged by the 470R (and the diode in series with it). This takes about 1/4 second and the cycle repeats.

The second block is a simple oscillator using a 32kHz watch crystal and a Schmitt inverter (between pins 3 and 4).

The output of this oscillator feeds into a buffer stage (between pins 5 and 6). The signal is prevented from reaching the buffer by the action of a gating diode on pin 5. The action of the 100k resistor is to allow the gating diode to turn the oscillator signal on and off without having to force against the output of the oscillator.

The fourth stage is a UHF transmitter. This consists of a single transistor set into operation by supplying base current via a 10k resistor, to produce a 303MHz signal modulated by the 32kHz tone. The duration of this waveform is about 1/4 second and this means the transmitter is operating for about 5% of the time. In this way we can have two small batteries power the circuit for many hours as the current is only about 25uA when timing and 3mA when transmitting. The coil for the output is etched on the PC board and it is designed to radiate RF energy when the oscillator is set into operation.

An RFC feeds current to the oscillator and is positioned at a nodal point to prevent interfering with the radiated signal. The frequency of the oscillator is set by adjusting the air trimmer across the coil.

An on-off switch turns the power off when the Minder is not required. The Panic button will over-ride this and can be pressed at any time.

#### BUILDING THE TRANSMITTER

All the components fit on the PC board supplied in the kit. You must build this kit on the PC board as the oscillator coil is part of the trackwork and its dimensions are critical.

Mount everything close to the board so that the leads of the components do not upset the frequency of the circuit. The

RFC does not play a critical part in setting the frequency so the spacing of the turns are not critical.

The crystal is not a polarised device and can be fitted either way around.

Set the air trimmer to mid capacitance in readiness for testing and connect the battery box via two short lengths of hook-up wire.

#### TESTING THE TRANSMITTER

The Minder is designed to operate at 303MHz and to test its operation we need to build the Field Strength Meter. This project is covered in Security Devices, P 13 and a UHF probe is connected to the front end to detect the high frequency.

As presented in Security Devices, the

coil can be fitted.

This coil is included in the Minder kit so that the modification can be made to those FSM units that have already been purchased.

To detect RF from the transmitter, the search coil is placed near the printed circuit coil and the panic switch pressed. This will allow the transmitter to operate continually.

You will need to be fairly close and maybe touching the transmitting coil to get a full scale dip on the meter. This will prove the transmitter is working.

Release the panic button and the circuit will revert to its normal mode of turning on for about 1/4 second every 9 seconds. Check the operation of this part of the circuit by measuring the time

between the pulses and make sure it is not longer than 10 seconds. When the circuit produces RF, the needle on the multimeter will move only a small amount due to the shortness of the beep, but you can be assured the transmitter is producing full power as this has just been proven.

#### THE RECEIVER

The receiver works on the principle of broadband reception at around 300MHz.

To increase the sensitivity of the front end, the transistor is allowed to oscillate or "ring." The 2.2uH choke and feedback capacitors create this ring.

The output is fed to two stages of amplification, followed by a 32kHz crystal, then two more stages of amplification. The next stage is a diode pump in which the signal is rectified by a set of

#### MODES OF OPERATION:

##### 1. Minder & Panic Mode:

The equipment constantly monitors the wearer. Transmitter on/off switch: ON. Receiver Sw 'A' OFF.

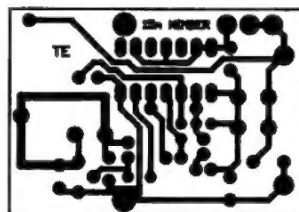
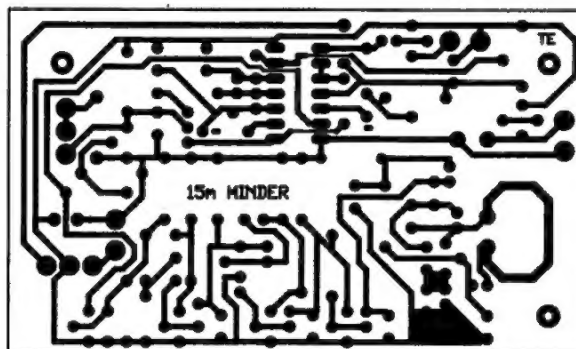
##### 2. Panic Mode ONLY:

Equipment does not constantly monitor wearer. Alarm sounds when panic switch is pressed. Transmitter on/off switch: OFF. Receiver Sw 'A' ON.

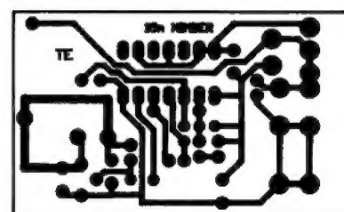
##### 3. EXIT MONITOR:

Monitors exits of buildings etc for transmitter beep. Alarm sounds when Transmitter comes within 15m. Transmitter on/off Sw ON. Receiver Sw 'A' not important.

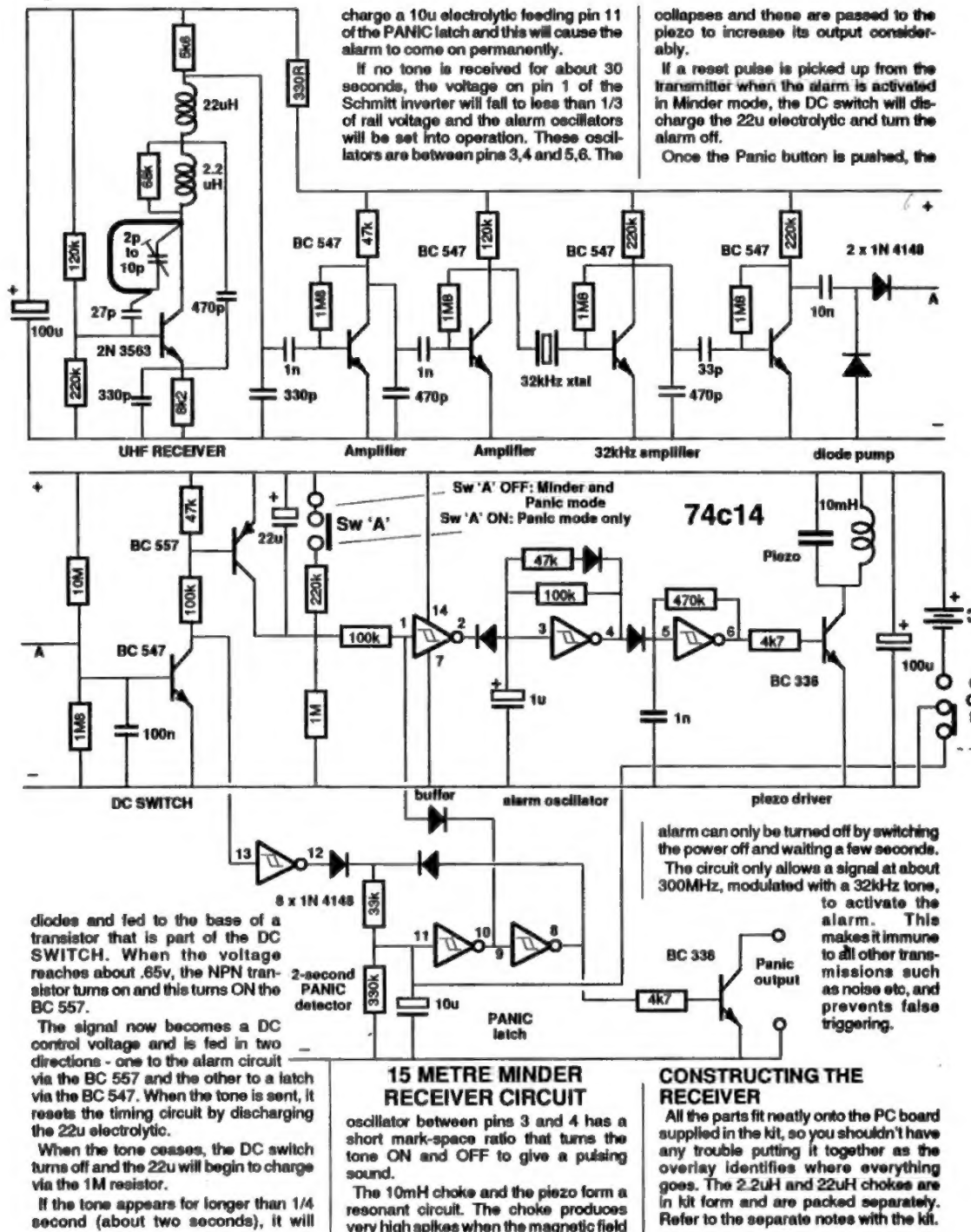
FSM is capable of detecting RF in the range 80-100MHz but for the higher frequency we need a different "probe." The new "probe" consists of a 5 turn coil fitted between the input capacitor and negative rail, in place of the 15 turn coil and extends over the edge of the board by exactly 1cm. The 15cm antenna wire is also removed so that this new search



Artwork for PP-12 box



Artwork for Tic Tac box



## TESTING THE RECEIVER

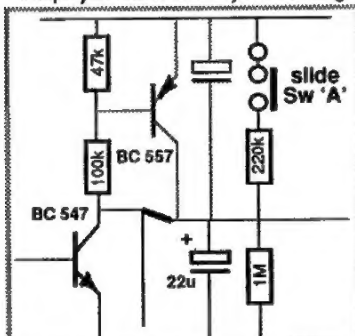
Firstly you must have the transmitter section working correctly - you will be using it to test the receiver. Place the transmitter about 50cm from the receiver and push the panic button. You can keep this button pressed with a weight during this part of the setting up.

With a plastic screwdriver, turn the air trimmer on the receiver until the alarm comes on.

Move the transmitter away about 2 metres and return the receiver to turn the alarm ON again.

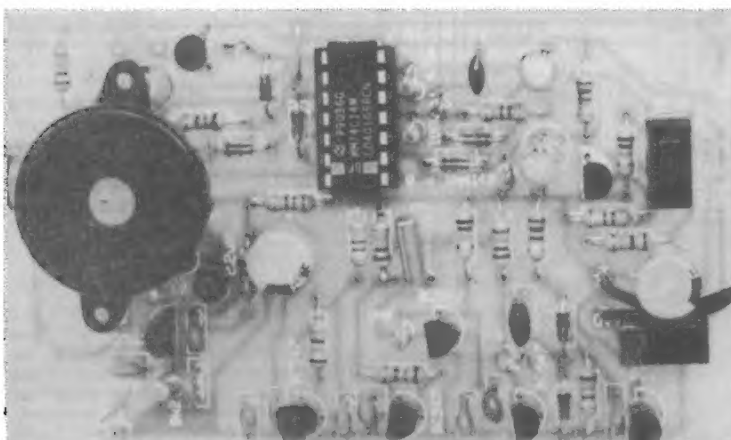
Have someone take the transmitter further away and push the button. Make sure the alarm comes on each time the button is pressed. A slight amount of peaking may be required to make sure both transmitter and receiver are on the same frequency. Test the Minder for range and you should get a comfortable 15 metres in a house, as we did with our prototype.

I hope you don't have anyone needing



### MODIFICATIONS for EXIT MODE

The circuit above shows the modifications required to turn the 15m Minder into an EXIT monitor. Remove the BC 557, place the 22u as shown and put a link under the PC as indicated by the thick line.



this project, but if you do, I'm sure it will come in handy.

If you position the receiver in the middle of the house, you will be able to cover all the rooms and the alarm will go off if the wearer wanders out the front door or too far away.

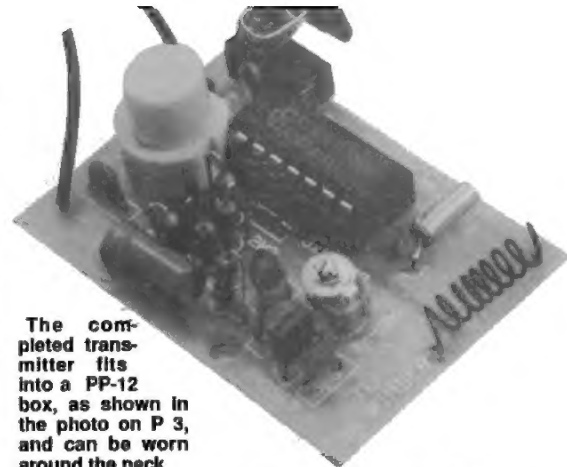
## IF IT DOESN'T WORK

If the project doesn't work, you have quite a complex problem on your hands. Because the transmitter works at 300MHz, you will need some fairly elaborate equipment to fully diagnose the high frequency sections. For instance, you will need a 100MHz CRO, a frequency meter and scanner or communications receiver to really get into the circuit and determine what is going wrong.

All we can suggest is the simple approach of using a multimeter and maybe a scanner. Firstly you will have to make sure the transmitter is transmitting at 300MHz. If you have a 10 - 30MHz CRO you can observe the waveform at the output of the first amplifier in the receiver. You will be able to see the 32kHz waveform coming through, as well as the "ringing" and noise picked up by the front end.

At the output of the crystal you will get a very clean waveform. Connect across the 1M resistor to see the operation of the DC switch.

The rest of the circuit can be checked with a multimeter. We don't have suf-



The completed transmitter fits into a PP-12 box, as shown in the photo on P 3, and can be worn around the neck

ficient space to go into more detail and if you are still having trouble, you should send both units to us for setting up and aligning. The cost is \$15.00 including return postage.

I hope all goes well.

We have produced two extra pages out-lining the construction of the two micro-Henry (uH) chokes and further notes on setting up. These pages come with the kit.

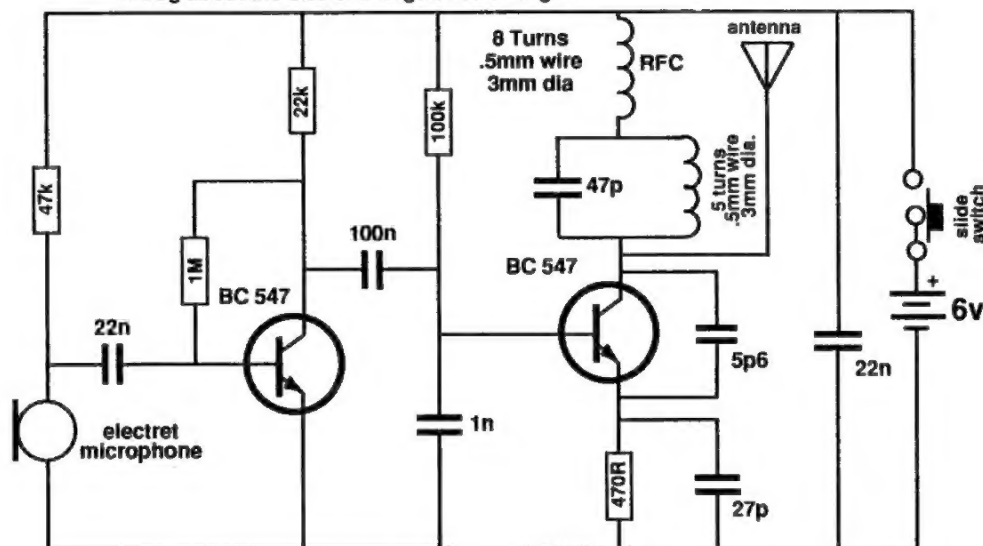
## RECEIVER PARTS LIST

- |          |          |
|----------|----------|
| 1 - 330R | 3 - 100k |
| 2 - 4k7  | 2 - 120k |
| 1 - 5k6  | 4 - 220k |
| 1 - 8k2  | 1 - 330k |
| 1 - 33k  | 1 - 470k |
| 3 - 47k  | 1 - 1M   |
| 1 - 68k  | 5 - 1M   |
|          | 1 - 10M  |
- 
- |  |
|--|
| 1 - 27p ceramic                        |
| 1 - 33p ceramic                        |
| 2 - 330p ceramics                      |
| 3 - 470p ceramics                      |
| 3 - 1n ceramics "102"                  |
| 1 - 10n ceramic "103"                  |
| 1 - 100n monoblock "104"               |
| 1 - 2p - 10p air trimmer               |
| 1 - 1u 16v or 25v electrolytic         |
| 1 - 10u 16v or 25v electrolytic        |
| 1 - 22u 16v or 25v electrolytic        |
| 2 - 100u 16v or 25v electrolytics      |
| 1 - 2.2uH choke (provided in kit form) |
| 1 - 22uH choke ( " " " " " " )         |
| 1 - 10mH choke                         |
| 5 - BC 547 transistors                 |
| 1 - BC 557 transistor                  |
| 2 - BC 338 transistors                 |
| 1 - 2N 3563 transistor                 |
| 1 - 32kHz watch crystal                |
| 8 - 1N 4148 diodes                     |
| 1 - 74c14 hex Schmitt trigger IC       |
| 1 - 14 pin IC socket                   |
| 1 - piezo diaphragm                    |
| 2 - spdt mini slide switches           |
| 2 - AA or AAA cells                    |
| 1 - 2-cell battery holder              |
| 1 - 15m MINDER RECEIVER PC             |

# CUBE OF SUGAR BUG

A Bug about the size of a large cube of sugar

**Parts & F**  
**PC Board (**  
**The LED Power**  
**testing the outpi**



**CUBE OF SUGAR CIRCUIT**

I have been asked so many times that I thought I should present it . . . I'm talking about the CUBE OF SUGAR BUG.

These bugs were offered to us during our early days of designing FM bugs, for the incredible price of about \$200 and we described them in an article some time ago. They came with a sheet of instructions that grossly exaggerated their capability and range.

It was when we were given one for repair that we found out how useless they were. The main problem was they use only a single watch-cell for the supply.

At a voltage of 1.2-1.5v, you cannot expect to get any output at all from the RF stage and this was proven by the fact that the one we tested had a range of about 30 metres instead of an expected 100 metres or so. On top of this the microphone was not very sensitive and the battery lasted only about 20 hours. In all it was a very poor design.

We have changed all that with our CUBE OF SUGAR BUG. Its big advantage is it uses 2 lithium cells to give a 6v supply and this gives it a range of about 500metres. The height of the two cells is only about 1/2cm and with a diameter of about 2cm they take up very little room for the energy they contain. To start with, each cell has a voltage of 3v and this means we only need two cells to produce 6v. The only problem with

lithium cells is connecting leads to the positive and negative terminals. This has been the problem with all our bugs as battery holders are usually more expensive than the cells themselves! To keep costs down we have opted for taping the cells together with electrician's tape and placing fine wire between the tape and the cell to make contact. If you are good at soldering you can solder fine leads to the terminals, but you must be very quick as any excess heat will damage the seal around the edge of the cell and they will leak. By using a 6v supply we can get a very good RF output while keeping the project to about the size of half a matchbox.

When completed, it looks like a very large cube of sugar and that's how it got its name.

The circuit is very similar to our VOYAGER project and uses standard components on a small PC board.

If you want to know where it fits in to our line-up, it comes between the Amoeba and Voyager both in complexity and range.

The PC is so compact that we have just been able to put a component overlay on it and you will have to refer to the large layout diagram for assistance when assembling to make sure everything goes in the correct place.

As far as construction is concerned, you should build some of our simpler

## PARTS LIST

- 1 - 470R All 1/4 watt resistors
- 1 - 22k
- 1 - 47k
- 1 - 100k
- 1 - 1M
- 1 - 5p6 ceramic
- 1 - 27p ceramic
- 1 - 47p ceramic
- 1 - 1n ceramic
- 2 - 22n ceramics
- 1 - 100n monolithic
- 2 - BC 547 transistors
- 1 - 5 turn enamelled coil .5mm wire
- 1 - 8 turn enamelled coil .5mm wire
- 1 - electret mic insert (small size)
- 2 - 3v lithium cells
- 1 - SPDT mini slide switch
- 1 - 3cm of 2cm heatshrink tubing
- 1 - 5cm red hook-up wire
- 1 - 5cm black wire (cut from antenna)
- 1 - 170cm antenna wire
- 1 - 30cm fine solder
- 1 - CUBE OF SUGAR PC BOARD

designs before tackling this one as the soldering needs a fair degree of skill to prevent shorts etc or overheating the components.

If you think you can put it together with a dirty iron and thick solder, you are wasting your time. The first thing you will do is create a short in the trackwork and blame us when the bug fails to work.



## HOW THE CIRCUIT WORKS

The circuit consists of two transistors and an electret microphone.

The microphone is actually an amplifying stage as it contains a Field Effect Transistor (FET) connected to a thin mylar diaphragm and it amplifies the sounds about 100 times before sending the signal to the first transistor stage - this is why electret microphones have a high output. If you include this, the circuit has 3 active stages.

The waveform at the output of the microphone passes through a 22n coupling capacitor to a common-emitter audio stage. Here it is amplified a further 70 - 100 times and is now large enough to be injected into the RF stage.

The operation of the RF stage has already been described in our other articles and it is sufficient to say that it operates at about 88MHz and is shifted in frequency by the audio injected into it.

It is this frequency shift or Frequency Modulation that produces the transmission called FM.

FM is by far the best way to transmit a signal as it is immune to most forms of interference such as car ignition, storms and other noise producers. All these affect the amplitude of the signal and that's why AM (amplitude modulated) signals are so noisy at the best of times and especially during a storm.

But FM is immune to changes in the amplitude of the signal and that's why it is so clean and clear. With an output as little as 10 milliwatts you can transmit up to a few hundred metres with a perfectly clean signal whereas it requires 200 milliwatts or more of AM to get 100 metres and the signal is very noisy.

## RANGE

With any type of transmitter, it is important to generate as much RF as possible to get the best range. It would be nice to generate 200 - 300 milliwatts of RF and reach 10km but this is not the purpose of these projects.

All our bugs are designed to teach you electronics and since they are all powered by batteries we have to keep the output down if we want to use small cells and have them last as long as possible. That's why we have kept the output to 10 milliwatts or so as you can get a surprising distance when you have an efficient circuit and a good radiator (antenna).

To achieve the maximum range with the Sugar Bug, we have improved the Voyager circuit by adding an RFC (Radio Frequency Choke). This is an 8 turn coil between the tank circuit and positive rail.

The RFC couples the output directly to the power rails as far as the current is concerned but allows the tank circuit to

produce a higher than normal waveform. It has the effect of separating the tank circuit from the positive rail for the signal.

The other component that has been added to this design is the 27p capacitor across the 470R emitter resistor. This allows the transistor to turn on harder without affecting the DC conditions.

The current taken by our prototype was measured at about 4mA. This makes the consumption about 24 milliwatts. We have not been able to measure the effective radiated power (ERP) from the antenna however by comparison with the Amoeba, we found the output to be about double. The consumption for the Amoeba is 7mA, making the power consumed 21 milliwatts and the reason why we get a higher output from the Sugar Bug is due to the higher supply voltage and the circuit improvements.

The secret to producing a high output is to have a high supply voltage and to keep the circuit very tight. This means keeping the components close to the board and making the PC tracks as short as possible.

This is very important when it comes to the wiring between the capacitor and coil in the tank circuit as the current that

passes between these two is very high and losses will occur if the tracks are not kept short.

## THE GROUND PLANE

In most of our designs we have relied on the size of the batteries to provide a good ground plane.

A good ground plane is needed by a circuit so that it can push the signal in and out of the antenna. A simple analogy is a trampoline.

If you sit the legs of a trampoline in soft rubber, the whole frame will move down every time you bounce and it would be difficult to get very high.

The same applies with small batteries. They form a very small ground-plane for the oscillator and the circuit finds it very difficult to push the signal in and out of the antenna. When the cells are larger they provide a much better ground plane and the output of the circuit is much higher - even without any other changes.

The 22n across the power rails also assists the oscillator by keeping the rails from spreading apart or coming together when the oscillator is operating. If the rails are not rigid, the oscillator does not have a firm reference from which to operate.



You must be very careful when soldering the wires to the electret mic to prevent it getting too hot. This will damage the FET and diaphragm inside the case and reduce the sensitivity. Even the slightest amount of overheating will make it become noisy and produce background crackles.



## THE MICROPHONE

The "sensitivity" of a bug depends heavily on the quality of the microphone.

We have been supplied with many different types of microphones, ranging from highly sensitive devices to very noisy units, and absolute rubbish.

Even though an electret mic consists of only two components, (a mylar diaphragm and a FET transistor), there is enormous technical know-how required to produce a good quality device. Very few applications require the degree of sensitivity that we need for our bugs and if you buy a microphone "off the shelf" or in a junk pack, you may be disappointed. Some mics are very noisy and as you drive them harder (to pick up faint sounds) the background noise increases and all you hear is a noise like "eggs frying."

Other microphones are as deaf as a post and require a load resistor as low as 4k7 for a 3v supply instead of 47k. All this does is increase the current consumption of the circuit.

We buy microphones in huge quantities and always test a sample before putting them in the kits. If you want to try microphones from other sources, you must use one of our good devices as a reference, so that you can compare one against the other.

## THE TRANSISTORS

If you wish to try other transistors in the RF stage, that's fine too. But first build the circuit and measure its output and range before changing the transistor. Some transistors should work better in theory but fail to come up to expectations because of the low supply voltage we are using. They need a higher voltage to get the performance you see in the specification sheets. Others need a higher base current and again, the current consumption goes up in line with the output, so you don't gain anything. If you find anything better than a BC 547, let us know. We have had lots of reports about better transistors but nothing has been proven.

One reader asked why we don't use a 2N 3563 in the oscillator/output, as it is an RF transistor. The reason is outlined above. It does not perform any better than a BC 547 at low voltage/low current so we have opted for the cheaper item.

## CERAMIC CAPACITORS

One small point that we haven't mentioned before is the quality of the ceramic capacitors we use in our circuits. There is a wide-held belief that ceramic capacitors are 'junk' and not suitable for high frequency work. This may have been the case many years ago but they have come a long way since then and are now quite suitable for all our applications. The low values we use in the

oscillator, such as 5p6, 10p and 47p have an additional characteristic called NPO and this means the value printed on the body does not change if the temperature increases or decreases (within limits). In other words they are very stable.

Again, if you buy capacitors "off the shelf" or in junk packs, you may not get NPO types and you will wonder why the circuit drifts on a hot day or produces crackles in the background, when exposed to hot conditions.

## CONSTRUCTION

As we mentioned earlier, all the parts fit onto a small PC board and the location of each part is shown on the overlay. This will make assembly very easy however you should not rush the job. Check with the photos and diagrams before starting.

There are two ways of building the project. One is to add one component at a time and solder it in place.

This is always recommended for beginners as it reduces the possibility of making a mistake. But when you are fairly adept at construction and wish to make the project quickly, you can fit all the parts onto the board, turn it over and solder all the leads.

As you add each component, the leads are splayed slightly to prevent anything falling out.

When we make the bugs for the Security Devices section of our business, we make them 10 or 20 at a time and this is how we do it.

The board has been designed to accept very small components but if a larger components has been included in your kit, you will have to bend the leads slightly to fit the holes.

Be careful with the transistors. They must be fitted as shown on the overlay and pushed close to the board so that they don't stick up higher than any of the other parts. When the leads are being soldered, you must do it quickly so that the transistor does not heat up.

Also, the enamel on the two coils must be scraped off the ends of the wire so that they will accept solder. The coils are pushed onto the board so that they touch the board. The 5 turn coil is the oscillator coil and can be stretched slightly to fit onto the holes. The 8 turn coil is the RFC

and is kept closely spaced in this project.

Once all the parts are soldered the leads are cut off and the board is ready for the switch and batteries.

The two lithium cells are placed together and wrapped with electrician's tape so that it stretches and keeps the cells in contact. Prepare red and black lengths of hook-up wire and poke them under the tape to make good contact. Fit heatshrink over the cells and shrink it tightly to make a battery-pack. Take the red (positive) lead to the switch and the negative to the board. Connect the other side of the switch to the board and the project is ready for testing.

## TESTING & TUNING

Switch the bug ON and place it near a radio. Tune across the band and you should hear a whistle near the lower end of the band.

If no whistle is detected, remove the antenna and fit the LED Power Meter or Peaker. If the multimeter does not give a reading, go to the If It Doesn't Work section. If a reading is detected, the bug may be transmitting off the FM band. This is most likely to be lower than 88MHz and to bring it higher, separate the turns of the oscillator coil.

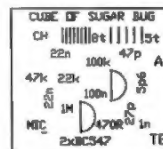
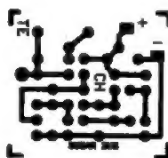
Pick a clear spot on the radio and to move the feedback whistle up the dial, separate the turns of the oscillator coil as we mentioned above. To move the feedback whistle down the band, push the turns together slightly.

Your bug is now ready for many hours of operation.

## IF IT DOESN'T WORK

If you have not used one of our kits for this project, don't even begin to look here for assistance. Your fault may be some of the odd parts you are using and we will never be able to cover all these possibilities.

At a quick glance, the Sugar Bug looks very simple but a lot of thought has gone into the layout of the board. For the circuit to work as well as it does, the layout is very important. If you change the wiring to a 'birds-nest,' the frequency will change considerably and the output may fall, or the bug may drift when it is touched or when the temperature changes. Even changing the diameter of the coil will make an enormous difference to the frequency.



Cube of Sugar Bug artwork.

The proximity of the components to one another is also very important and most High Frequency circuits work better when the parts are close together.

When you build one of our kits, all the engineering and layout has been done for you and the project should work first go.

But things can go wrong and when they do, many constructors either trash the project or ring us in desperation. We get calls such as: "Help! My bug doesn't work!" or "It only goes 1 metre or it whistles! - what's wrong!" As you can appreciate, we can't spend time on the phone diagnosing everyone's project. That's why we have the "If It Doesn't Work" sections. But when we ask the caller if they have done any preliminary testing they say "Oh no, I thought you could fix it for me over the phone!"

Of course we can fix anything but I think these callers have missed the point. All our projects are designed to teach YOU electronics. And when it doesn't work, it provides a perfect opportunity to study the circuit and locate the problem.

Before you start on the bug, replace the two lithium cells with 4 AA or AAA cells so that the circuit is easier to work on.

Then check to see if the bug is producing an output by placing it near a radio and listen for a feedback whistle while tuning across the entire band. If nothing is detected, the bug may be transmitting on a frequency outside the band. The output can be checked another way by removing the antenna lead and connecting the Peak or Led Power Meter to the antenna point. If no RF is detected the fault will lie in the oscillator section.

Before you make any further tests it's a good idea to make sure the Peak or Led meter and multimeter are working by testing them on another bug such as the Amoeba. This way you will know that the test equipment is working and you can get some idea of the reading to expect.

RF is generated by the high frequency section of the bug and if nothing is produced, almost any of the components could be at fault. For instance the 22n across the power rails is essential and any of the components in the oscillator stage will certainly cause the oscillator to mal-function. Some of the faults will be easy to detect but if the 47p capacitor is open circuit or the transistor has been overheated, how are you going to find these minute faults? The answer is, you can't. The only way to tackle the circuit is to replace the components, one at a time, until it comes to life.

But before you start replacing anything, the first thing to do is to check for obvious faults such as poor soldering or shorts and bridges. Make sure all the component values are correct and the enamel has been scraped off the coil

before it was soldered to the board. Simple things like this account for 95% of the faults. The chances of a ceramic going open or a resistor failing is a million-to-one and the only type of low-value capacitor I have found to be open-circuit, in my years of servicing TV's, was a mica capacitor. I have never had any trouble with ceramic capacitors. Oh, yes I have. One capacitor was shorted in a project sent in for repair due to overheating and another had fallen apart due to a very hot iron softening the solder inside the capacitor. They can also crack due to rough handling and this will create a short where the raw edges are exposed to the outside.

In case you are not aware, the leads of these capacitors are soldered to two small discs of metallised ceramic and if you get the capacitor too hot, the leads will fall off.

Next check the current consumption of the project. If it is only about 1 or 2 milliamps, the oscillator stage will not be working at all and a good bet is the oscillator transistor. It could also be a fault in the base bias (such as the 100k not making contact) or a short between base and ground, causing the transistor to be cut-off (not conducting).

If the current is about 4-6mA, the transistor could be damaged due to overheating when soldering (this will damage the crystalline structure and cause the transistor to lose gain). It may be oscillating but at the wrong frequency or have a very small output.

The only other possibility is "a very loose circuit" where the components have not been pushed close to the board. If you don't do this, the extra lead length creates a high impedance path for the signal and reduces the waveform so that the output is only a fraction of that expected. The answer is to push everything close to the board and make sure none of the transistors have been overheated.

If you have any doubt at all, replace the components or build another kit. For the cost of another kit you can make sure you get it right next time and I am sure it will work first go. You can then come back and either replace all the components of the first project, or compare one project against the other and work out where the fault lies. No matter how you do it you are going to learn more than any text book can provide. The main thing is to never let a fault beat you. The satisfaction and reward of finding the fault yourself will give you the encouragement to tackle more difficult problems.

The oscillator section produces the CARRIER and this can be picked up on a radio as a "quiet spot." Once you can detect this you know the oscillator is working and is on or near the correct

frequency.

The next step is to make sure the audio from the microphone is being amplified and passed to the oscillator section. The easiest way to test the audio section is to listen for a feedback whistle from the radio. If you don't hear anything, bring the bug closer and turn the volume up. This should produce a feedback whistle and if it doesn't, the audio stage may be at fault.

Check the voltage on the collector of the audio transistor. It should be at mid rail but can be slightly above or below this and still provide the necessary gain. The voltage on the electret mic can be as low as 70mV or as high as 1v and the microphone will (or may) be working correctly. Make sure the case of the microphone goes to the negative rail.

If all this fails to produce audio, reduce the bias resistor to the microphone to 10k and connect the output directly to the base of the oscillator stage via a 22n capacitor. This will bypass the audio stage and you can check the microphone directly.

If you have access to a CRO, you will be able to follow the path of the audio signal and locate the fault very easily. CRO's are ideal for doing this and the most likely cause of poor or absent audio will be a short across the microphone, a short between base and negative rail of the audio transistor or an open coupling capacitor.

The CRO will also detect if you have a faulty microphone such as one that has been damaged by overheating, high reverse voltage or maybe a fault in manufacture. Don't put anything into the hole at the front of the mic as this will damage the diaphragm and it will lose sensitivity.

If you don't have a CRO, the front end can be checked by removing the microphone and taking it to another bug or using the microphone from another project as a comparison. The audio stage can be checked by connecting it to an audio amplifier but the best method is to connect the front end of two bugs in parallel and use a slide switch to change from one pre-amplifier to the other. You must remember to disable the RF stage of one bug so that the two do not conflict. This should cover just about all the possible faults and the project should be working by now.

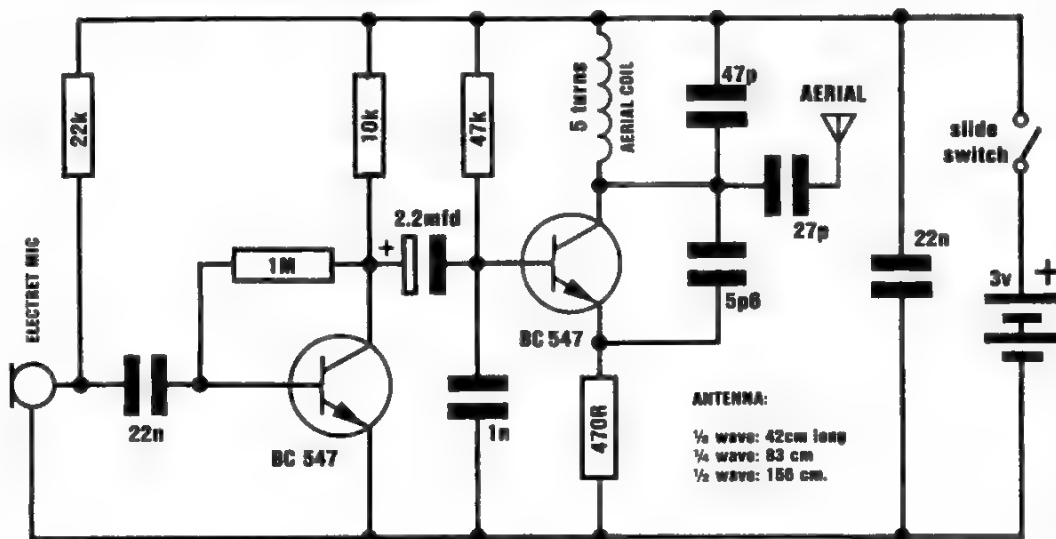
Refit the two lithium cells and look around for a small plastic box to put the project in.

Very soon we hope to produce a small box especially for our range of bugs and if time and money permits, we will stick them to the cover of a forthcoming issue. Look out for it. Until then, keep up the good work.

# FM BUG

Part  
PC B

No Bugs with this BUG. A guaranteed performer using readily available parts.



## COMPLETE FM BUG CIRCUIT

Corporate espionage is reaching new heights in sophistication. The latest information to be released shows the depths firms will go to pry into a rival firm's operations.

By using the latest in electronic bugging, they have stolen information, secrets and even formulas known only to the inventors themselves.

Take the example of one firm:

Leaks from Top Management level remained a mystery until, one day, a bug was discovered inside the Managing Director's office.

Sitting prominently on his desk was a gift box of imported cigars!

Cleverly concealed in the lower part of the box was a miniature FM transmitter ... all a gift from a phoney sales rep.

This is just one of the many bugging devices available on the eaves-dropping market. The range includes pen and pencil holders, trophies, framed pictures and office furniture with false bottom drawers.

These products are readily sold to fledgling companies, eager to nestle into big brother's market.

And for a while these bugging devices worked. Few firms knew of their existence, and even less on how to sniff them out.

But that has all changed now. If a corporation suspects a leak at any level, the first thing they order is an investigation into security. Not only personnel, but information and electronic security.

Debugging has grown into big business. Most large security organisations have

**Everyone has been absolutely amazed at the performance of this bug.**

..... a section concentrating on electronic surveillance including bugging and debugging.

They use scanners to detect hidden devices and can locate absolutely anything, anywhere, and on any frequency.

It was only after the firm above had commissioned a scan of the entire floor, that the cigar box was discovered. Its innocence had deceived everyone. And cost them a small fortune!

Bugging of this kind is completely illegal and we don't subscribe to this type of application at all.

## PARTS

- 1 - 470R  $\frac{1}{4}$ watt
- 1 - 10k
- 1 - 22k
- 1 - 47k
- 1 - 1M
- 1 - 5.6pf ceramic = 5p6
- 1 - 22pf ceramic or 27pf or 33pf
- 1 - 47pf ceramic
- 1 - 1n ceramic = 1000pf or 102
- 2 - 22n ceramic = .022 or 223
- 1 - 2.2mfd 16v or 25v PC electro
- 2 - BC 547 transistors (Not SGS type)
- 1 - mini slide switch spdt.
- 1 - electret microphone (insert)
- 2 - AAA cells
- 10cm tinned copper wire
- 2 - metres aerial wire
- 1 - FM BUG PC board
- 1 - Toothbrush case.



But the uses for our SUPER-SNOOP FM WIRELESS MICROPHONE can be harmless, helpful and a lot of fun.

Our unit is both compact and very sensitive and can be used to pick up even the faintest of conversations or noises and transmit them 20 or so metres to any FM receiver.

When you build the FM BUG you will see why we consider the design to be very clever. We have used only low priced components and they are all easy to obtain.

No air trimmer capacitor is required as the coil is squeezed slightly to obtain the desired frequency. This has allowed us to fit the bug into a tooth-brush case so that it can be carried around or placed on a shelf.

If it is set between two books it will be hidden from view or as a supervision accessory it can be placed on a small child, etc. The transmitted signal will over-ride the background noise and the output will be clean. If the child wanders beyond the range of the transmitter, the background noise will come up and signal that the tot is out of range.

As an added bonus, you can listen to the chatterings and squabbles as the children amuse themselves in the back yard.

It is also great for picking up the first signs of a child awakening from his afternoon sleep as it can be used as an indicator from a bed-ridden patient.

The great advantage of the bug is the absence of wires. And since it draws only about 5 - 10 milliamps, the pair of AAA cells will last for many months.

The success of this FM BUG is the use of TWO transistors in the circuit. To create a good design, like this, each transistor should be required to perform only one task. In any type of transmitter, there is a minimum of two tasks.

One is to amplify the signal from the microphone and the other is to provide a high frequency oscillator.

The amplified microphone signal is injected into the oscillator to modify its frequency and thus produce a **FREQUENCY MODULATED** oscillator. If an aerial is connected to the output of the oscillator, some of the energy will be radiated into the atmosphere.

To increase the output of our design, an RF amplifier would be needed but this gets into legal technicalities with maximum transmitting power.

It may be of interest to know that a record distance of 310 miles was achieved with a 350 micro-watt transmitter in the USA, some 16 years ago. This equates to an astounding ONE MILLION miles per watt!

In simple terms, an RF amplifier becomes a LINEAR amplifier. This can be seen as per the second transistor in the Polykit design as presented in issue 4.

We have opted for sensitivity and the first transistor is employed as a pre-amplifier. This will enable you to pick up very low-level sounds and transmit them about 20 to 50 metres.

### MAKING THE OSCILLATOR COIL

The only critical component in the FM BUG is the oscillator coil. When I say critical, I am referring to its effect on the frequency. Its critical nature only means it must not be touched when the transmitter is in operation as this will detune the circuit completely.

It is the only component which needs to be adjusted or aligned and we will cover its winding and formation in detail.

The oscillator coil is made out of tinned copper wire and does not need any insulation. This is not normal practice but since the coil is small and rigid, the turns are unable to touch each other and short-out.

The coil is made by winding the tinned copper wire over a medium-size phillips screw-driver. The gauge of wire, the diameter of the coil and the spacing between turns is not extremely important and it will be adjusted in the alignment stage. However when the project is fully aligned, it must not be touched at all.

Don't be over-worried at this stage. Just follow the size and shape as shown in the diagram and everything will come out right in the end.



The coil has 5 turns. To be more specific, it has 5 loops of wire at the top and each end terminates at the PC board. The coil must be wound in a clock-wise direction to fit onto the board and if you make a mistake, rewind the coil in the opposite direction.

A pre-wound coil comes with the kits supplied by the magazine however you can make your own very easily in a few minutes.

Collect all the necessary components and lay them on the work bench ready for the next stage:

### CONSTRUCTION

Construction is quite straightforward as everything is mounted on the printed circuit board. The only point to watch is the height of some of the components. The capacitors and electrolytic must be folded over so that the board will fit into the case.

Positioning of the parts is not as critical as you think as the final frequency is adjusted by squeezing the coil together or stretching it apart.

However it is important to keep the component leads as short as possible and the soldering neat due to the high frequencies involved. The components must be soldered firmly to the board so that they do not move when the transmitter is being carried.

Even the poorest of soldering will work but who wants to see poor soldering on a project? Especially when it is housed in a clear perspex case.

The soldering may not affect the resulting frequency but poor layout of the components certainly will.

All the resistors must be pressed firmly against the PC board before soldering and the two transistors must be pushed so that they are shorter than the opening in the case.

Some BC 547 transistors will not work in the circuit. Maybe the frequency is too high. SGS BC 547 transistors did not work at all. The other two types: fBC 547 and Philips BC 547 worked perfectly.

All the small-value capacitors are ceramic as they are not critical in value and do not need to be high stability. But you must be careful when identifying them. It would be a very simple mistake to buy a 56pf instead of 5p6 because there is no difference in the size. 22n may be identified with 223 or 22n or .022. A capacitor marked 22k will be a 22pF cap and will not be suitable. The 1n capacitor may be marked 1n or .001 or 102. These are all the same value. The value 101 or 103 is NOT 1n so be careful, the caps may be about the same size. The rule is: don't use a capacitor unless its markings are clear and you are sure of the value.

The switch is mounted on the PC board with its three terminals fitted into the large holes.

Later, a square cut-out will be made in one half of the plastic case so that the slide of the switch protrudes through.

The final items to add to the board are the two AAA cells. These are available at Tandy stores and we have chosen them for slenderness so that they can be fitted side-by-side in the case. A small piece of tape will keep them together ready for connecting into circuit.

It is very difficult to solder to the zinc case but if you roughen the surface with a file and use a large, HOT, soldering iron, the job can be done very quickly. Use a piece of tinned copper wire to join the positive of one to the negative of the other. At the other end, solder longer lengths of wire so that they can be connected directly to the PC board. Make sure the positive terminal connects to the plus on the PC board.

AAA cells are also obtainable at photographic shops. The only alternative is an 'N' cell which is nearly as thin as an AAA cell but only half the length. If all this fails, you can use 2 AA cells in a long tooth-brush tube by connecting them end-to-end.

The terminal marked A on the board is the antenna output. For a frequency of 90MHz, the antenna should be 165cm long. This is classified as a half-wave antenna and provides one of the most effective radiators. If you find the antenna gets in the way you can opt for a quarter-wave antenna and this will be 83cm long. If you only require to transmit 10 to 20 metres the antenna can be as short as 42cm or even as low as 5 or 10 cm.

The most suitable length will depend on the sensitivity of the FM radio used to pick up the signal and the obstructions between the transmitter and receiver. It will be a good experiment for you to 'cut' your own antenna and determine which is the most suitable for your application.



**MEMO from Gino:** If you decrease the 22k to 10k or 4k7, the BUG becomes even more sensitive! See his BIG EAR project in the next issue.

## HOW THE CIRCUIT WORKS

The circuit consists of two separate stages. The first is an audio pre-amplifier and the second is a 90MHz oscillator.

The first stage is very simple to explain. It is a self-biasing common-emitter amplifier capable of amplifying minute signals picked up by the electret microphone. It delivers these to the oscillator stage. The amplification of the first stage is about 100 and it only operates at audio frequencies. The 22n capacitor isolates the microphone from the base voltage of the transistor and allows only AC signals to pass through. The transistor is automatically biased via the 1M resistor which is fed from the voltage appearing at the collector. This is a simple yet very effective circuit. The output from the transistor passes through a 2.2mfd electrolytic. This value is not critical as its sole purpose is to couple the two stages.

The 47k, 1n, 470R and 22n components are not critical either. So, what are the critical components in this circuit?

The critical components are the coil and 47pF capacitor. These determine the frequency at which the bug will transmit. In addition, the effective capacitance of the transistor plays a deciding factor in the resulting frequency.

This stage is basically a free-running 90MHz oscillator in which the feedback path is the 5p6 capacitor.

When the circuit is turned on, a pulse of electricity passes through the collector-emitter circuit and this also includes the parallel tuned circuit made up of the oscillator coil and the 47pF capacitor. This pulse of electricity is due to the transistor being turned on via the 47k resistor in the base circuit.

When ever energy is injected into a tuned circuit, the energy is firstly absorbed by the capacitor. The

electricity will then flow out to the coil where it is converted to magnetic flux. The magnetic flux will cut the turns of wire in the coil and produce current and voltage which will be passed to the capacitor.

In theory, this current will flow back and forth indefinitely, however in practice, there are a number of losses which will cause the oscillations to die down fairly quickly.

If a feedback circuit is provided for the stage, the natural RESONANT frequency of the coil/capacitor combination will be maintained. The 5p6 provides this feedback path and keeps the transistor oscillating.

The 5p6 feeds a small sample of the voltage appearing at the collector, to the emitter and modifies the emitter voltage. The transistor sees its base-to-emitter voltage altering in harmony with the resonant frequency of the tuned circuit and turns the collector on and off at the same frequency.

Thus there is a degree of stability in the oscillator frequency.

The actual frequency of the stage is dependent upon the total capacitance of the circuit and this includes all the other components to a minor extent.

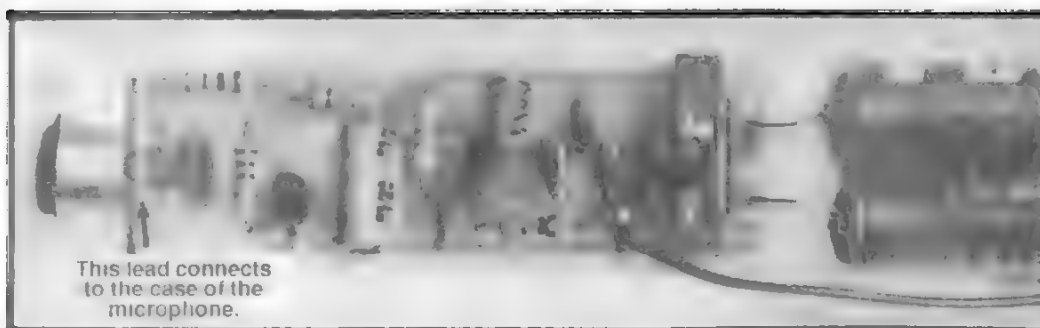
Once the basic frequency of 90MHz is set, the variations in frequency are produced by the changes in effective capacitance of the transistor. This occurs when its base voltage is increased and reduced. The electret microphone picks up the sound waves which are amplified by the first transistor and the resulting frequency is passed to the base of Q2 via the 2.2mfd electrolytic.

This alters the gain of the transistor and changes its internal capacitance. This junction capacitance modifies the oscillator with a frequency equal to the sound entering the microphone thus FREQUENCY MODULATING the circuit. A short length of antenna wire is connected to the collector of the oscillator via a coupling capacitor and some of the energy of the circuit will be radiated to the surroundings.

Any FM receiver will pick up this energy and decode the audio portion of the signal.



The completed BUG in the clear plastic case. The aerial wire supplied is sufficient for a 165cm half-wave antenna and can be cut to 83cm or shorter, depending on the range you require.



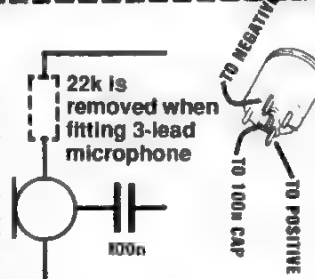
### 3-LEADED ELECTRET MIC:

If you have a 3-leaded electret microphone, it can be used in the circuit provided a simple modification is made. Three-leaded mics

have internal dropping resistors and thus the 22k resistor in our circuit is not needed.

All microphones are polarity sensitive and must be inserted into the circuit around the correct way. See the accompanying diagram.

The 2 holes in the PC take the negative pin and the output pin. A jumper wire is taken from the positive pin on the mic to the positive line on the PC, at a point where the 22k meets the positive rail.



### SETTING UP THE TRANSMITTER

When the FM BUG is complete, checked and ready for insertion into its case, there is one slight adjustment which must be made to align it to the correct frequency.

As we have said, the only critical component is the oscillator coil. It is the only item which is adjustable.

Since we are working with a very high frequency, the proximity of your hand or even a metal screw-driver will tend to de-tune the oscillator appreciably

For this reason you must use a plastic aligning stick to make the adjustment. Any piece of plastic will do. A knitting needle, pen barrel or plastic stirring stick can be used.

Place the bug about a metre from the FM radio and switch both units on. Tune the radio to an unused portion of the band and use the alignment stick to push the turns of the coil together. Make sure none of the turns touch each other as this will short out the operation of the oscillator.

All of a sudden you will hear the background noise diminish and you may even get feed back. This amount of adjustment is sufficient. Place the BUG in its case and tape up the two halves.

The fine tuning between radio and transmitter is done on the radio. Peak the reception and move the BUG further away. Peak the fine tune again and move the BUG into another part of the house and see how far it will transmit.

### IF THE BUG FAILS

If the bug fails to operate, you have a problem. Simple digital tests will not fix it nor will ordinary audio procedures. The frequency at which the BUG operates is too high.

You have to use a new method called comparison.

This involves the comparing of a unit which works, with the faulty unit.

This means it is ideal for a group of constructors to build a number of units and compare one against the other.

This will not be possible with individual constructors and they will have to adapt this fault-finding section.

The first fact you have to establish is the correct operation of the FM receiver.

If you have another BUG and it is capable of transmitting through the radio you know the radio is tuned to the correct frequency. Otherwise you will have to double-check the tuning of the dial and make sure the radio is switched to the correct setting.

The next stage is to determine if the BUG is functioning AT ALL. The only voltage measurements you can make

are across the collector-emitter terminals of the first transistor (1v to 1.5v) and across the collector-emitter terminals of the second transistor (1.3v to 1.5v) These values won't tell you much, except that the battery voltage is reaching the component.

Tune the radio to about 90MHz and lay the radio antenna very close to the antenna of the BUG. Switch the BUG on and off via the slide switch. You should hear a click in the radio if the BUG is on a frequency NEAR 90MHz. Move the turns of the aerial coil together or apart with a plastic stick as you switch the unit ON and OFF.

If a click is heard but no feed-back, the oscillator will be operating but not the pre-amp stage. This could be due to the electret microphone being around the wrong way, the transistor around the wrong way, a missing component or an open 2.2mfd electro.

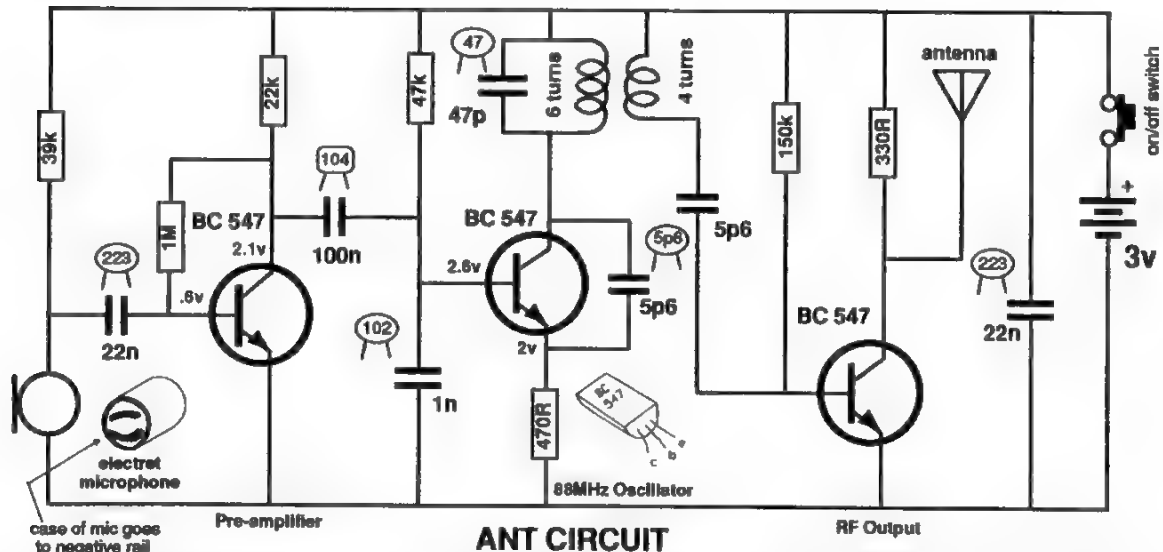
If the fault cannot be located, compare your unit with a friend's. You may have made a solder bridge, connected the batteries around the wrong way, made the coil too big or used the wrong value capacitor for one of the values.

If all this fails, put the unit aside and start again. This time buy a complete kit and see how much more success you have.

# THE ANT

A very stable BUG. Can be carried and moved while in use.

## Parts & PC Board



All the projects in this book have been given a name. An insect name. During their design, we called them all 'bugs' and it was difficult to differentiate one from another.

Then Ross suggested we give them names corresponding to their size or function. Thus we called this one the ANT. It's small (but not as small as the mini bug described later in this book) and the name ANT fits perfectly.

Before setting on a particular project, you should read the notes on all the projects as each has something different to offer. The theory behind a simple FM transmitter is considerable and we have tried to present as many facts as possible, but split between each of the projects.

One of the features of this project is the fact that it is frequency stable due to the resistive output. This enables it to be carried around without drifting off the band. It is also very compact and has a good range. It has been primarily designed for this type of application, such as minister or lecturer, where the talker must move around while talking.

It can be made even more compact by using button cells for the supply. We have opted for AAA cells in our discussion as their size provides a considerable duration of operation and they can be soldered in place to fit inside a Tic Tac box.

You could just as easily use two button

cells if you are careful with a soldering iron. But is not advisable to solder them and you should bend up some clips to hold them in place. Some of the commercial lapel FM microphones are beautifully designed and we have included a photo of one of these in this article to show you what to aim for.

But their range was considerably less than we had hoped for and so you cannot compare the two. Its another one of those things that look nice but fall short in performance.

A brief outline of the ability of the 'ANT' will help you compare it with our other designs. The ANT will transmit up to about 200 metres under fairly favourable conditions but when you carry it around, the range is reduced to 20 - 50 metres.

It transmits on the 88 - 108MHz FM band and must be tuned to an unused portion of the band so that it does not interfere with local radio stations.

Frequency range and fidelity is superb on FM and the reproduction is crystal clear. You can use this project for listening to wild-life, animal tracking and husbandry, remote listening for security purposes, as an early warning alarm or for transferring TV sound from one room to another. Its uses are limitless and it is especially useful for situations where it is required to be moved or carried, such as for stage-work.

We will leave the ideas up to you. Kits for the ANT (and also all the other

### PARTS LIST

- 1 - 330R (orange-orange-brown)
- 1 - 470R (yellow-purple-brown)
- 1 - 22k (red-red-orange)
- 1 - 39k (orange-white-orange)
- 1 - 47k (yellow-purple-orange)
- 1 - 150k (brown-green-yellow)
- 1 - 1M (brown-black-green)
- 2 - 5p6 ceramics
- 1 - 47p ceramic
- 1 - 1n ceramic (102)
- 2 - 22n ceramics (223)
- 1 - 100n monoblock (monolithic) (104)
- 3 - BC 547 transistors
- 1 - 6 turn .61mm tinned copper wire 3mm dia coil
- 1 - 4 turn .5mm enamelled wire 3mm dia coil
- 1 - electret microphone
- 1 - mini slide switch
- 2 - AAA cells
- 1 - 170cm antenna wire
- 1 - ANT PC BOARD

projects are available by mail-order from Talking Electronics and by using the step-by-step notes on the following pages, you can't go wrong.

Without any more discussion, let's start.



## HOW THE CIRCUIT WORKS:

There is a lot more to the circuit than first meets the eye.

**Some components perform one task, others perform more than one task and everything is fairly critical.**

The value of some of the parts is more critical than others and also the placing and spacing of the components is important. This is because the circuit is operating at a high frequency and we want it to operate at peak performance.

Starting at the left hand end of the circuit, we have an electret microphone. As we have mentioned before, this microphone houses an FET (Field Effect Transistor) in which the lead equivalent to the base of a normal transistor, the GATE. The gate is connected to a small metallised diaphragm that is charged with a high potential during manufacture and it holds this charge for the life of the unit.

The diaphragm forms a miniature capacitor or condenser (and this gives rise to its name 'condenser microphone'). When sound waves touch the diaphragm, the charge on the gate of the FET alters. The FET amplifies this and the result appears on the output lead.

These microphones are very sensitive and produce a very good output swing with normal levels of speech.

The 22k resistor is the load resistor and supplies the microphone with a potential. When the microphone picks up signals, the varying voltage across the field effect transistor is passed to the first BC 547 via a 22n capacitor. This value is not critical and has been chosen as it is the largest value ceramic having a small size.

The BC 547 is a self-biasing audio amplifier and is used as a pre-amplifier to boost the output of the microphone to a level suitable for injecting into the oscillator stage.

The transistor is biased via the 1M base resistor and provides a gain of about 100.

The main purpose of the stage is to provide microphone gain so that the circuit will pick up faint sounds (it can be made more sensitive by lowering the value of the load resistor to the electret to 10k or 4k7) and the result is the wireless microphone is nearly as sensitive as the human ear. If this stage is removed, it will be necessary to talk directly into the microphone and the unit will only pick up direct speech.

The output 100n can be any type of capacitor and we have used a mono block mainly for its small size.

The second BC 547 is wired as an oscillator operating at about 100MHz. The frequency has been set by the value of the components in the collector and emitter circuits and also those in the base and coupling circuits.

In other words, the frequency is set by nearly everything in the circuit, including the battery voltage and 22n battery-decoupler. The only components that do not affect the frequency are the pre-amp parts and microphone.

The oscillator stage is turned on via the 47k and this causes a current to flow in the collector-emitter circuit. Connected to the collector of the transistor is a parallel tuned circuit made up of a capacitor and coil.

When a pulse of energy is passed through an arrangement such as this, the capacitor initially stores a charge and this energy is then passed to the coil. The energy is converted to magnetic flux and a very short time later, the magnetic flux cuts adjacent turns and this produces electrical energy that flows back into the capacitor. This phenomenon is called **RESONANCE**.

In theory this action will go back and forth indefinitely however in practice there are a number of losses in the capacitor and coil and gradually the packet of energy will decrease.

This is where the transistor comes in. It is designed to supply a small amount of energy at each cycle to keep the oscillations at a maximum.

This is done by picking off a small amount of voltage from the collector and feeding it to the emitter. This is done via the 5p6 and the low value of this capacitor has been chosen so that it does not dampen the oscillations too much.

The third transistor is inductively coupled to the oscillator by interleaving 4 turns (called the secondary) with the main coil. The 'pick-off' 5p6 capacitor is a low value and means only a very small sample is picked off. This prevents any loading effect on the oscillator.

The output transistor is turned on slightly by the 150k base resistor and the waveform picked off by the secondary of the air-cored transformer is passed to the base.

The function of the 5p6 is two-fold. Firstly it allows a turn-on voltage to be applied to the base via the 150k and secondly it transforms the package of energy from the secondary of the transformer into a form suitable for the transistor.

The energy output of the transformer comes in a form that is high voltage and low current. The transistor requires low voltage and high current. The capacitor converts the package of energy into this form.

The transistor amplifies this waveform and the current through the collector-emitter is modified to produce a carrier wave.

The carrier is picked up by an FM receiver and when the 'ANT' is tuned in, the background noise reduces to almost zero. When speech is picked up by the microphone, the output frequency is modulated and the receiver converts this back into speech.

This frequency modulation is performed in the oscillator stage. Signals picked up by the electret microphone are amplified by the first transistor and appear on the base of the oscillator stage. The 1n capacitor plays an important part in the process. This is how it works:

The base of the transistor is trying to move up and down in sympathy with the emitter. But at 90MHz, the 1n provides a restraint and the result is the base is held firm (at a voltage level of about 1.3v) and this permits the oscillator to function.

Along comes the audio waveform and because it is a much lower frequency, the 1n does not have any hold on the voltage and the base is allowed to rise and fall.

This alters the gain of the transistor and alters its internal capacitance. Thus the frequency of the oscillator changes an amount equal to the waveform entering it. This is called **FREQUENCY MODULATION** and produces a very clean transmitting signal that is distortion-free.

The circuit is tuned by adjusting the spacing of the oscillator coil. A common alternate approach is to include a variable capacitor across the coil so that it can be adjusted. These trimmers are difficult to obtain and are quite expensive. They also take up more space.

Ours is the better approach as once the frequency is set, it does not require any further adjustment.

Moving the coils apart or together alters the frequency quite appreciably and this must be done carefully so as not to shift the frequency off the band.

The main coil has 6 turns and secondary 4 turns. This means a turns ratio applies between the windings and because the secondary feeds into a 5p6 only a fraction of the energy of the tuned circuit is picked off.

The purpose of the linear amplifier output stage is to reduce the effect of external capacitance on the circuit. This is important if you want to move the unit around or wear it as a lapel mic.

The output stage reduces the loading effect of the aerial and also 'tightens up' the whole circuit so that it is not sensitive to outside capacitive effects.

The final component is the 22n across the battery. This is necessary to reduce the internal impedance of the power supply. The capacitor stabilises the supply rails and allows peak amounts of current to be drawn without affecting the rest of the circuit. This capacitor is also called a 'supply decoupler' and at 90MHz it is very effective.

## CONSTRUCTING THE 'ANT'

The following step-by-step construction notes show how and when each component is added to the board. And by following this, you are almost guaranteed success.

Lay out all the parts on a clear portion of the work-bench and identify everything.

You should be able to read the value of each component and know that some of them must be inserted around a certain way.

The soldering iron should be clean and you should have a pair of side cutters for clipping the leads after each component has been soldered.

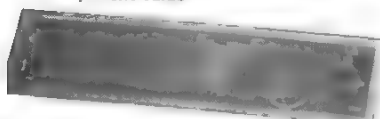
Here we go:



Lay out all the parts similar to this photo. Make sure everything is present by comparing with the parts list. If a component is not marked as stated in the list, it may be the nearest value or a slightly better value. Don't worry too much at this stage unless you are sure it is wrong.

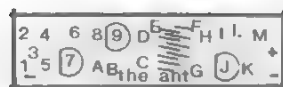
There is one extra resistor in the kit. It is a 10k and should be used as the mic load resistor if you want the ANT to have super-sensitive pick-up.

Inspect the board. It has numbers and letters on it in place of component values. This was necessary as the board was too small to write each component value.



Construction does not follow the numbering but goes across the board in a linear mode so that you have plenty of room when fitting each component.

Check the underside of the board for damaged tracks, especially here and here.



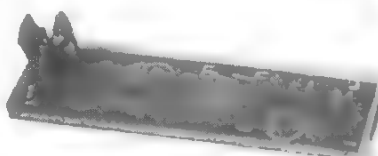
Make sure the legend is readable and that all holes have been drilled. Check the underside of the board for correct track-work and see that all tracks are etched correctly and that no fine 'hairs' of copper have been left to cause shorts between tracks.



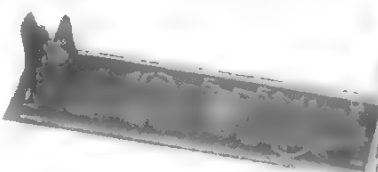
The first component to be mounted is a 22k resistor (red red orange). Bend one lead over close to the body of the resistor and fit the two leads down the holes marked '2', so that the resistor touches the board. Solder it in position and cut the two leads close to the board. This applies to all the resistors in this project and they can be placed either way around as it does not matter which hole gets the body of the resistor. It will depend mainly on the room available on the board.



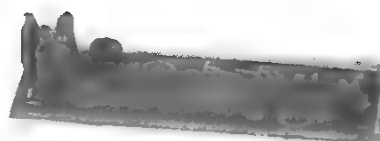
The next component is a 22n ceramic capacitor (marked 223 on the body). It fits down the holes marked '3' and touches the board. It can be placed either way around and soldered quickly so that it doesn't get too hot. Cut the leads close to the board to make a neat job.



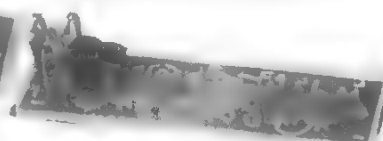
The third component to be added to the board is a 22k (red red orange) resistor. It is fitted over the '4' on the PCB board and like the first resistor, the leads are cut off close to the board, after it has been soldered.



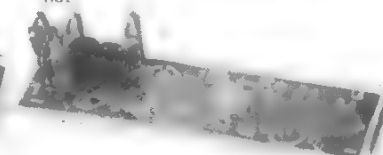
Next fit a 1M (brown black green) resistor over the holes identified by the number '5'. Solder it and cut the leads as before.



Next is a 100n monoblock. It is identified by 104 on the body and these numbers will be very small and hard to see. It can be placed either way around on the board and goes down holes marked '6'. It is soldered quickly to prevent it overheating. Clip the leads close to the board.



Next fit a BC 547 transistor so that it is level with the top of the 1M resistor. It goes down the three holes marked '7' and the flat on the side of the transistor matches up with the flat on the overlay. Solder the leads quickly as the transistor does not like to be overheated. You can hold the transistor in place with a finger and this will act as heatsink to let you know if the transistor is getting too hot.



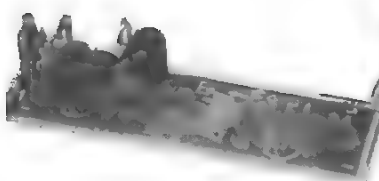
Next fit the 47k (yellow purple orange) resistor down the holes marked '8' and keep it nicely upright with one hand while soldering with the other. Clip the leads and check your board against the photo.



Next the 1n ceramic (marked 102 on the body). This goes down the holes marked 'A' and touches the board both before and after soldering so that the project looks as compact as possible.



The second BC 547 transistor is now added to the board. This fits down the holes marked '9' and as before, solder it quickly to prevent it getting too hot.



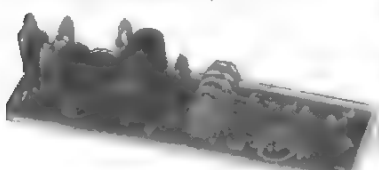
The 470R (yellow purple brown) resistor is fitted down the holes marked 'B' and soldered like the other resistors. Clip the leads close to the board and we are nearly halfway through construction



Next fit the 47pF ceramic down the holes marked 'D', as shown in the photo. This capacitor will be marked 47 on the body and should be soldered quickly like all the capacitors



The next component is a 5p6 ceramic and fits down holes marked 'C' on the board. It can be marked 5 6 or 5p6 and can be fitted either way around



Now comes the most critical part. The main oscillator coil determines the frequency of operation and its size and shape is very important. It must look exactly like that shown in the photo to get the ANT to transmit on the 88 - 108MHz band. The kit contains a pre-wound coil but if it has been squashed or damaged, it must be rewound

The coil consists of 6 turns of 71mm tinned copper wire wound on a 3mm Philips screwdriver shaft



Fit the ends of the coil down the holes as shown in the photo and this will create the correct spacing between turns. Solder the ends and cut the excess off close to the board



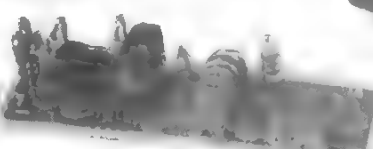
The secondary winding consists of 4 turns of 61mm enamelled wire wound on a 3mm shaft. Bare the ends by scraping them with a nail file or sand paper so that the enamel is completely removed and fit the ends down the holes on the PCB board as shown



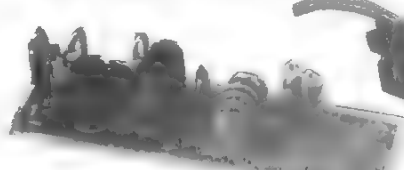
Interleave the turns with those of the tinned copper wire coil. Start at the top and you will find the other end will fit down the appropriate hole on the board. Solder the ends and clip the surplus close to the board



Next fit a 5p6 ceramic down holes marked 'G' on the board. Solder the leads and clip them the same as the other parts. Check your model with the photo to make sure everything is identical



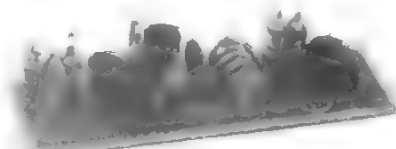
The next item is a 150k (brown green yellow) resistor and this goes down holes marked 'H'



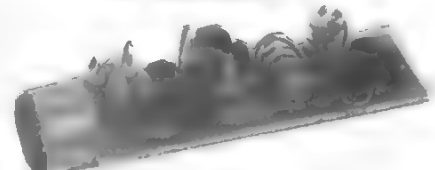
The 330R (orange orange brown) resistor fits down holes marked 'I' and solder it as neatly as the other resistors



The third and final transistor is now fitted and this BC 547 fits down the three holes marked 'J'. Don't let the transistor project higher than the top of the resistors



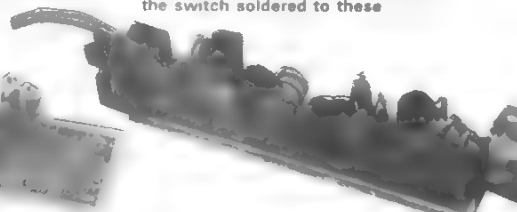
The last capacitor to add is a 22n (marked 223 on the body) and it fits down holes marked 'K'



The electret microphone must be fitted so that the lead going to the outside of the case goes down the hole marked negative '-' on the board. By checking the copper side of the board, you will notice it goes to the negative terminal of the battery.



The photo shows how the switch is added to the top of the board. Short lengths of tinned copper wire are soldered to the board and the tags of the switch soldered to these



The aerial wire is taken to the hole shown and soldered in place. It should be cut to 156cm for 1/2 wave or 83cm for 1/4 wave. Try a half wave antenna first and if the range is not required, go to 1/4 wave



The two AAA cells are connected together by soldering the switch between the positive of one cell and the negative of the other. Refer to the photos to see how a link is required between two terminals of the switch so that it will operate correctly.

At the other end, a short length of tinned copper wire is soldered between the negative of one cell and the negative hole on the PC board. A short length of insulated hook-up wire is soldered to the positive of the other cell and the positive hole on the PC board.

The project is now complete. Check your model against the photos and it is ready for testing.

### SENSITIVITY

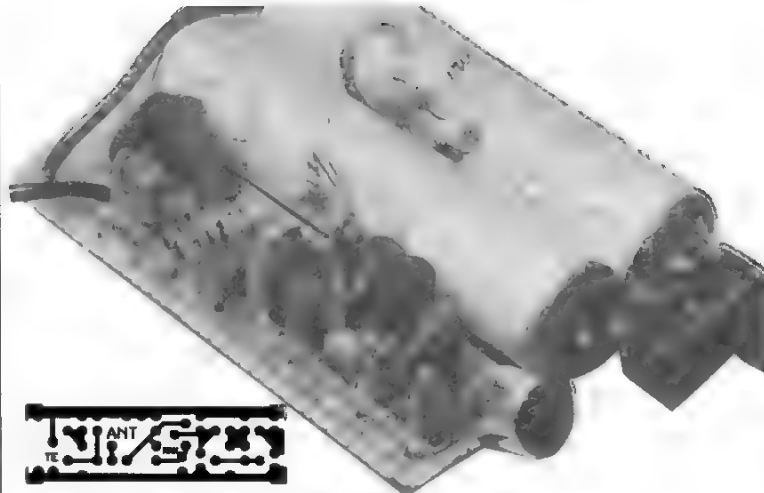
The sensitivity of the ANT depends to a large extent on the value of the load resistor for the electret microphone. We have used 39k in the kit as the microphone we have supplied is a very sensitive type. If you wish to increase the sensitivity to super-performance, the resistor can be decreased to 22k but don't go any lower otherwise the circuit will 'oscillate' or 'motor-boat.'

### NOTES ON THE ELECTRET MICROPHONE

There are a number of electret microphones on the market and the difference between them is considerable. Some have high sensitivity while others are low sensitivity.

All our circuits call for a high sensitivity two-leaded type and this is where the problem arises. Some look like three-leaded devices but are really two. They have two short leads and a thick earth tag next to one of the leads.

These are two-leaded types and you have to connect the closest lead to the earth tag to make it into an obvious two-leaded type otherwise only a buzz



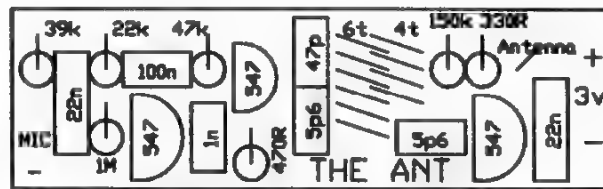
Three leaved microphones are a bit different. They have a low-value resistor (about 220R to 1k) built into them so that they can be connected directly to a 1.5v to 3v circuit without the need for any additional resistor.

But if you want to operate them on more than 3v, an external load resistor must

will not work satisfactorily on re-assembly.

Some electret microphones are larger than others. Both work on the same principle and have the same output waveform when supplied with a voltage if they have the same sensitivity.

But some produce a very high output



An enlarged view of the ANT overlay

be added. The resistance of this should be between 10k and 47k.

Three-leaved microphones can be used in our circuits by connecting the earth lead to the negative rail and the

while others are extremely poor. There is not way to find out the difference without putting them into a circuit. The size of the waveform is governed by the quality of the electret material and there is nothing you can do to change its properties.

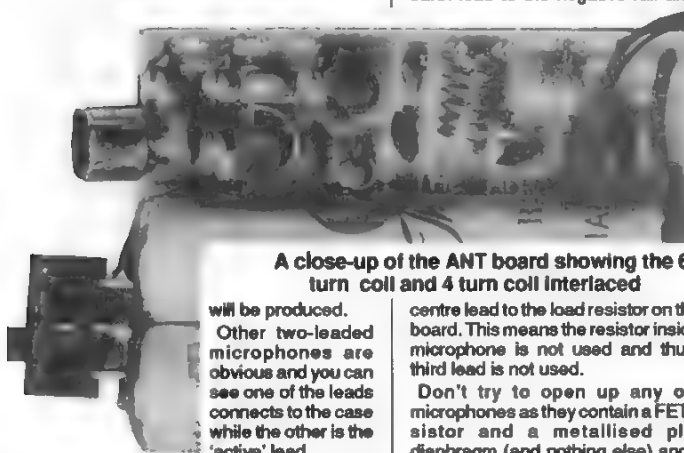
Electret microphones do not produce a voltage or current but rather modify a voltage across a load resistor.

They are an active device (due to the presence of a transistor) and must be placed in a circuit around the correct way.

You must not put a voltage directly across them as this may damage the transistor. They must be placed in series with a resistor.

Some microphones come with long leads and can be soldered directly to the board. Others will need leads applied and when doing this, do not overheat the microphone as the diaphragm is very easily damaged.

If the microphone produces a lot of background noise, like bacon and eggs frying, the microphone is damaged.



A close-up of the ANT board showing the 6 turn coil and 4 turn coil interlaced

will be produced.

Other two-leaded microphones are obvious and you can see one of the leads connects to the case while the other is the 'active' lead.

centre lead to the load resistor on the PC board. This means the resistor inside the microphone is not used and thus the third lead is not used.

Don't try to open up any of the microphones as they contain a FET transistor and a metallised plastic diaphragm (and nothing else) and they



## TESTING

At first you may think the method of testing a transmitter is around the wrong way. This is because we start at the output stage and work towards the front end.

But when you look at it more closely, you will see the reason for this.

Once you have the output stage working, you have a starting point and from there the procedure is fairly straight-forward.

Once you have read the 'How it works' section, you will realise the output waveform of the transmitter consists of two parts. The base part is called the 'carrier' and this is a constant frequency. If we are transmitting at 100MHz, it is a 100MHz frequency. Added to this is the audio component and this causes the 100MHz to increase an amount equal to the audio frequency being picked up by the microphone.

The audio tone **FREQUENCY MODULATES** the carrier and this gives us the term FM transmission.

We use this knowledge to fault-find the project. Our first concern is to be able to detect the carrier. This is picked up on an FM radio as a 'dead spot' and by turning the transmitter off, the background noise will appear.

The carrier is produced by the oscillator stage and if a linear amplifier is present, it will pass the carrier to the aerial. When we detect a carrier, we prove that both stages are working.

If a dead spot is not heard, we can firstly assume that the frequency of transmission is off the FM band.

To adjust the transmitter, all you need do is close up the turns of the oscillator coil (making sure the turns do not touch each other if bare tinned copper wire is used).

Sweep the entire FM band on the radio, looking for a silent spot. The bandwidth of the transmitter will be quite narrow and it will be necessary to sweep the band fairly slowly.

If nothing is heard, go over some of the simple faults such as making sure the project is turned on, the radio is on the correct band (88MHz to 108MHz), the radio has an antenna connected and no metal objects are near the transmitter etc.

You must detect a carrier before progressing any further. This is the starting point and no other sections can be tested until this is successful.

Unless you have a 100MHz CRO, there is no other way to see if the project is transmitting. This is not entirely true as another solution is to make a second model.

If the second model works successfully (and I see no reason why it shouldn't), you can use it to physically check the spacing of the coil, placement of parts and the position on the FM band, to see why things are not coming through on the first.

When a dip is heard, you are half-way home. In fact you are 90% home. The rest is down-hill.

The next step is the testing of the audio stage or stages. Even though the project contains one audio stage, we can consider the microphone to be a stage since it is an active device containing an FET transistor.

If either the microphone or pre-amplifier stage does not work, you will not get any more than a carrier output.

The testing of these two stages is covered in the section 'More Tips on Fixing The Projects' and you should read this and follow it through.



**Testing is done a little differently than you expect.**

**You don't need any elaborate test gear - just an FM radio.**



If this fails to locate the fault, you can use almost any CRO to pick up the waveform at any one of a number of points on the board. It is important to note that you will not be able to transmit when making these tests but this is not necessary as we have already proven the oscillator is producing a carrier.

By whistling into the microphone and picking up the waveform at the output of the mic. (at the point where the load resistor connects to the microphone), you will be able to see the peak-to-peak performance of the microphone.

Next, pick up the waveform at the other end of the coupling capacitor and note that some of the amplitude has been lost.

This point is also the base lead of the audio transistor and it is handy to make a calculation of the gain of this stage.

This is done by whistling at a set distance from the microphone to get say a 5mV p-p waveform. By going to the collector of this stage, (and adjusting the vertical amplifier of the CRO), you will be able to read the peak-to-peak value after amplification.

It should be at least 500mV, giving a gain of 100.

This waveform is injected into the base of the oscillator stage via a DC blocking capacitor and causes it to change frequency as mentioned before. Finally you will be able to detect the audio waveform at the emitter of the oscillator stage and this will prove the audio component is flowing through the circuit.

If the gain of the audio amp stage is less than 100, the transistor should be replaced as it may be leaky or faulty in some way. The only other cause of low gain is the two biasing components being incorrect.

Once the circuit is working successfully, the final stage is peaking the transmitter so that it achieves the range we have stated. If you require only a short range, the project need not be peaked at all. The aerial can be almost any length and providing you have picked a spot on the band that is away from any other radio station, the job is done.

If you want more than a few metres range, you will have to trim the aerial to  $\frac{1}{2}$  or  $\frac{1}{4}$  wave and set the frequency to approx mid band. Adjust the position of the two cells and set everything exactly as it will be placed in the final test position. Move the transmitter to the next room. Fine tune the radio and listen for such things as a ticking clock.

If the background noise level comes up, you may have to provide an antenna for the FM radio. They are usually a folded dipole, looking very much like the letter 'T' and when this is added to the radio, its range increases enormously. Also the transmitter gives the best range when the aerial is allowed to fall vertically.

Our prototype had a range in excess of 200 metres when carried about in a built-up area.

This is how we tested it: Paul went down to the fish and chip shop with the transmitter placed in his top pocket and the antenna dangling inside his jumper. We could hear him cross the main road some 150 metres away, enter the shop, place the order and hear the ding of the cash register.

Between the shop and our receiver was two layers of glass, two houses and a span of back yards. This is the range to be expected when the unit is peaked and a 9v battery fitted. The 9v supply did not achieve a greatly increased distance, and may be not worth the extra cost. With 3v, the transmitter started to fade out just before entering the shop. Nine volts allowed us to pick up conversation inside the shop and this represents only about 20% improvement.

When peaking up the 'ANT', the air cored transformer plays a very important role. It can be peaked by moving the secondary winding into the main coil or detuned by withdrawing it. This way you can create the range you require.

## SETTING UP THE 'ANT'.

This is how it is done: Place the 'ANT' about 1 metre from an FM radio and switch them both ON.

Tune the radio from one end of the band to the other and listen for a feedback whistle. When this is heard, switch the transmitter off and tune the receiver to the closest radio station, either side of the transmitter frequency.

The transmitter must be operated on an unused portion of the band and must not interfere with any other radio station.

If a station is very close, the transmitter will have to be moved along the band. This is done by pushing the turns of the main coil together slightly and repeating the above to see how far the frequency has shifted. These turns can also be spread out to shift the frequency in the other direction.

Once a clear channel has been found in the middle of the band, the coil is not touched again.

If the background hiss dies down from the receiver but no feedback whistle is heard, it indicates the carrier section is working but not the pre-amp or microphone stages.

To fix this, you will have to read the next section on fault finding.

The fine tuning between the transmitter and receiver is done at the receiver end. Move the transmitter away about 10 metres or so (preferably into another room) and fine-tune the receiver slightly to pick up the transmitter as strongly as possible.

Once you are satisfied that the circuit is working equally as good as our description, you can fit it into a TIC TAC container.

If you prefer to use another case remember it is preferable to use a plastic case so that it doesn't have any effect on

the performance. A metal case may shift the frequency or deaden the oscillator and reduce the range.

After fitting, the only part you will have to hide is the aerial and at the cost of reducing the range, it can be cut down to 5 or 10cm.

In our field tests, the range was 200 metres in a built-up area and 250 metres in a line-of-sight operation. All these tests were done with an 83cm  $\frac{1}{4}$  wave antenna.

This range makes the ANT ideal for large halls or for sporting events where a 100 metre range is required.

On 3v, the circuit consumes about 5mA and the life of the battery will be about 100 hours.

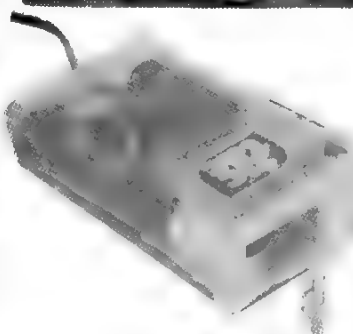
The transmitter can also be operated on 9v and our tests showed the range to be about 250metres in a built-up area and 300metres in a line-of-sight operation.

In other words, 9v did not increase the range very much and we consider 3v is the best choice.

By now I hope everything is working perfectly and you are ready to test the range.



This commercial FM transmitter is beautiful but it doesn't perform very well. We get only about 5metres out of it. It's only a single transistor model and the microphone is not very sensitive.



## FITTING THE 'ANT' INTO A CASE

The 'ANT' is designed to be fitted into a TIC TAC box and the photo shows how this is done.

A cut-out is made in the bottom of the box for the slide switch with a hot soldering iron and a small file.

The flip-top lid hides the microphone and it can either be left open, removed or a hole drilled to allow the sound to enter. A small hole will not produce as much clarity as an exposed microphone and you will have to accept a balance between appearance and performance.

Once the case arrangements have been made it will be necessary to 'SET UP' the transmitter and make sure it is working correctly.

## MORE TIPS ON FIXING THE PROJECTS:

These notes apply to all the circuits in this book and only slight differences apply to each design.

If any circuit does not work exactly as described, don't despair. It's now that you will pick up a lot of servicing tips.

The equipment you will need is a multi-meter, soldering iron and tools, an uncluttered bench and an FM radio.

All the circuits have been tested and are guaranteed to work. But if one doesn't, there could be one of a thousand reasons. Most of the time it will be due to a simple mistake such as two resistors or capacitors swapped over or a connection that has not been properly soldered.

These are very hard to locate and quite often someone as remote from electronics as your sister, mother or wife can spot a simple mistake as they will see the project with new eyes.

Don't over estimate yourself. It's the simple mistakes that can be so easily made - and so hard to fix!

Talking Electronics provides a repair service but, as you can imagine, the cost of repairing a low-priced project can be more than the initial cost of the kit!

That's why we don't expect these kits to be sent in. We want them to be fixed by you and that's why so much of the book is devoted to getting them going.

There are two ways of going about this. One is to fiddle around making a few voltage checks along the way and somehow, eventually, the thing gets fixed. The other is to make up a second kit and using this as a foundation, repair the first.

This may be an expensive way of going about it as you could finish up with two non-working models. But look on the bright side, you should finish up with two working models and have learned a lot in the meantime.

The idea is to use the second kit to fix the first by swapping one part at a time. You must remember which model is which!

When the second fails to work and the first springs into life, you know the fault has been located.

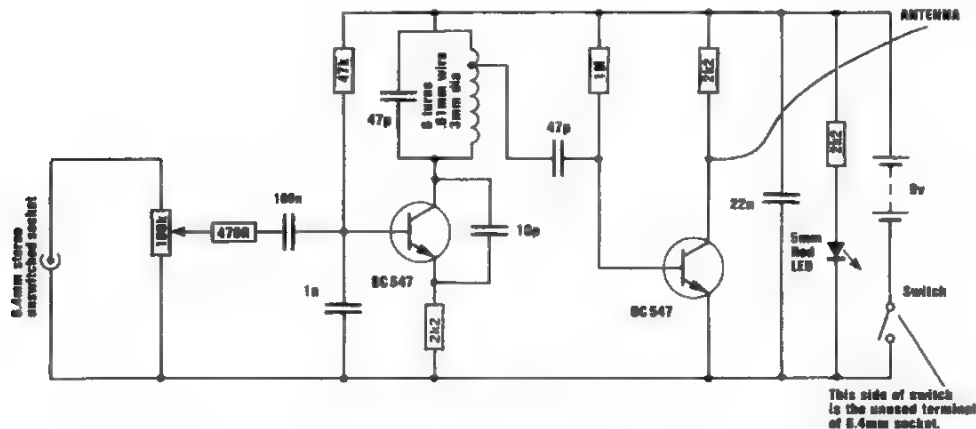
If, on the other hand, both models become non-operational, you may have located one of the faults and at this point you should swap the components back again to get unit two working. Put a new component in model one and keep going.

Eventually every component will be transferred and both projects must fire-up. This might be slow and expensive but how else would you be able to locate an open 5p6 capacitor or a dry 2.2mfd electrolytic? (These could have been damaged during assembly or soldering).

# BEETLE Mk II

TRANSMITS YOUR GUITAR TO AN FM TUNER

Parts & PC: \$  
PC Board only \$1.



BEETLE Mk II CIRCUIT

The Beetle Mk II is also known as AIR LINK Mk I when made up in completed form. We have it in kit form as well as completely made up. See the list of products at the back of this book for ready-made units.

Beetle Mk II is an improved version of the Beetle project described in FM BUG book number 1 and has a number of changes to allow it to operate on 9v.

The circuit is designed to switch ON when the 6.4mm plug is plugged into the socket and it connects to the output of a guitar via a short patch cord.

The kit comes complete with socket, box, led mount and 9v battery. All you have to do is put it together.

The main difference with this design is the input attenuation. It can be adjusted to allow the circuit to match almost any guitar.

The output from a guitar can range from a very low level to hundreds of millivolts and to prevent overloading the input circuit, a preset pot is included. This pot can be adjusted through a hole in the side of the case.

The main requirement for a guitar transmitter is stability. It must not drift when a player moves around. This has been achieved with the ANT circuit (converted for 9v operation) and with a few changes including a tapped oscillator coil.

The project needs a reasonable degree of skill to put together and you should have built some of our other designs to understand what is required. If you've done this, let's go:

## CONSTRUCTION

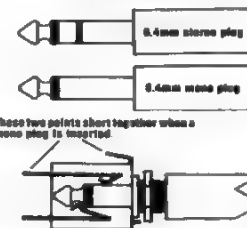
All the components are fitted onto the "BEETLE" PC board and due to the compact nature of the layout, a lettering and numbering system has been used to identify each component.

Refer to the large layout for the value of each part and everything is straightforward until you come to the tapping on the oscillator coil. This is made on the 3/4 turn from the positive end. You can refer to the Amoeba project for assistance with this and the ANT project for identifying each of the components.

The board fits down the slots of a small jiffy box and a hole is drilled in the side of the case so that the mini trim pot can be adjusted with a miniature screw driver during the set-up procedure.

Two leads are required for the 'Power-ON' LED and three for the input socket as well as two for the battery and you should refer to the wiring diagram to see how to connect these together.

When everything is wired up, the project can be set to the desired frequency by adjusting the oscillator coil. The best frequency is about 88.1MHz to 88.5MHz.



Using a mono plug in a stereo socket to act as a switch as well as an input.

## PARTS LIST

- 1 - 470R (yellow-purple-brown)
- 3 - 2k2 (red-red-red)
- 1 - 47k (yellow-purple-orange)
- 1 - 1M (brown-black-green)
- 1 - 100k mini trim pot
- 1 - 10p ceramic
- 2 - 47p ceramics
- 1 - 1n ceramic
- 1 - 22n ceramic
- 1 - 100n monoblock
- 1 - 5mm red LED
- 2 - BC 547 transistors
- 1 - 9v battery snap
- 1 - 9v battery
- 1 - 6 turn coil .61mm wire 3mm dia
- 1 - 160cm hook-up wire for antenna
- 1 - LED mount
- 1 - 6.4mm stereo socket unswitched
- 1 - H 0205 jiffy box with plastic lid
- 1 - BEETLE Mk II PC BOARD

## FITTING THE PARTS INTO THE CASE

Everything is a tight squeeze but firstly 4 holes have to be drilled: one to take the LED mount, one for the 6.4mm socket, one for the antenna and one for the mini trim pot adjustment.

The quickest way to make the holes is with a hot soldering iron and finish off with a tapered reamer but this is not as good as the right size drill taken carefully through the plastic.

The socket should be mounted between the guides so that it fits flat against the side of the case.

The LED mount fits together from both sides and the leads of the LED can be soldered to the circuit, remembering the short lead goes to the negative rail on the PC.

Feed the antenna through the hole and mount all the items in the box.

The plastic lid can now be screwed on but firstly the guitar strap is fitted between the lid and case, and the 4 screws tightened up. This will clamp the strap in place and hold the case just where you want it. Use a patch lead (about 60cm long) between guitar and case and fit the antenna on top of the strap and hold it in place.

The unit is now ready for use and when a 6.4mm plug is inserted into the socket, the circuit is supplied with current. The socket has contacts that short together when the plug is inserted and this acts as a switch.

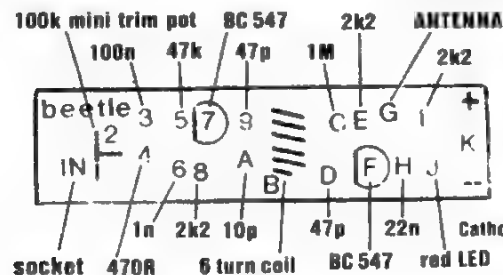
You will need an FM tuner (88 - 108MHz) or FM radio with output socket and this is taken to the input of a power amplifier to complete the system.

Connect a patch lead between guitar and Beetle and you are ready for testing.

## TESTING

Turn the volume of your amplifier to a low setting so as not to blast you out of the room. Turn the guitar volume to about 7 or 8 and adjust the pre-set pot to give a clear, undistorted, output.

Adjust the trim pot fully clockwise and anticlockwise to hear distortion and zero output so that you are familiar with these and make sure the final setting is not near the unwanted levels.



The range for the Beetle will be about 30 to 50 metres and most important the frequency will be very stable.

We tried the Air Link in a shopping centre and it went down the Mall and around the corner without fading out.

You should pick a low frequency that is free from interference such as 2-way couriers etc. About 88.1MHz to 88.5MHz will be suitable for one unit and if you want another in close proximity, it should be between 88.6MHz and 88.9MHz to prevent interference.

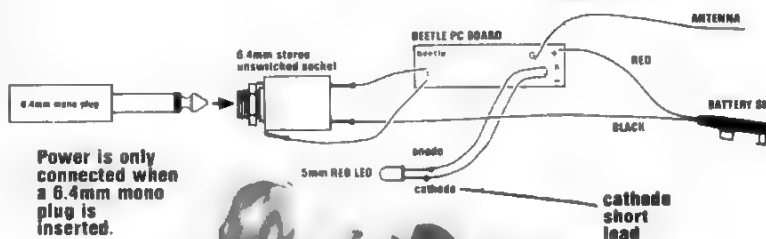
Obviously you don't want them on the same frequency as you need to mix the signals. Don't forget to remove the plug when not using the transmitter, to save power.

When you get your Air Link operational, you will never go back to coily cords!

It'll be the best investment you ever made.

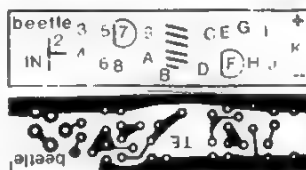


All the parts fit into a small Zipper box size: UB-5.



Power is only connected when a 6.4mm mono plug is inserted.

The fully assembled board ready for the leads.



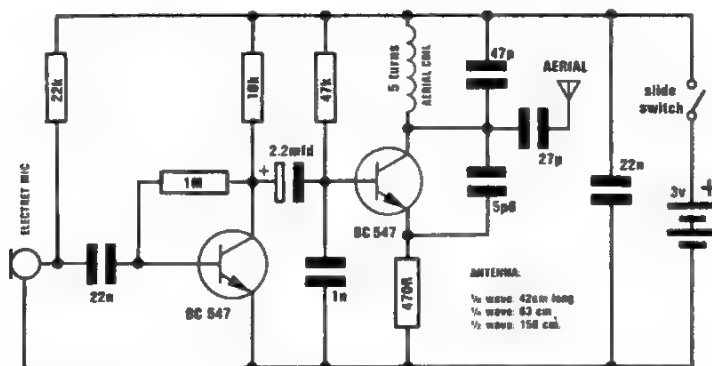
Full-size PC board and overlay for those who want to make their own boards.



# THE GNAT

Parts & PC  
PC Board c

A MICRO VERSION OF THE FM BUG



GNAT FM TRANSMITTER

This is one of our smallest bugs in the series and is designed to be placed in an inconspicuous place and left there. We have called it the GNAT to keep it in line with our series of bugs.

It is small enough to be hidden in a desk ornament, hollow book or clipped under a table so that it can pick up all the surrounding sounds.

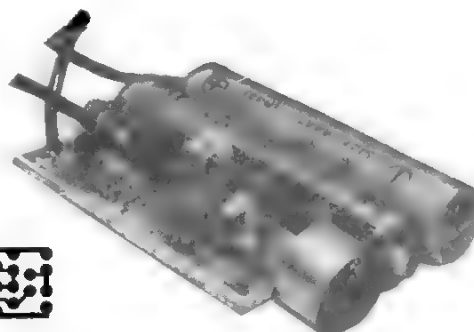
In the diagram, the PC board is smaller than the batteries but if you use small cells, the operating time will be reduced. You can use button cells but they are expensive, do not have a very high capacity and are difficult to connect.

AAA cells are the best and will power the project for about 100 hours for standard cells or 200 hours for alkaline cells.

The circuit and characteristics of the Gnat are identical to that of the FM Bug and neither project can be carried around as the frequency will drift slightly if the antenna is near or touching the body.

The circuit is extremely sensitive and is better than the human ear when a sensitive microphone is used. The sensitivity of the microphone depends on its load resistor. This can be between 22k and 47k. We have included the most suitable value in the kit and at this stage it is 47k as we have purchased a large quantity of very sensitive microphones and these require on a very small current for their operation.

The range of the Gnat will depend mainly on the length of the antenna and it can be as short as 5cm. At this length



the range will only be a few metres, so if you want the full range, you should use the 170cm antenna and stretch it out fully.

The project is small enough to be placed inside a matchbox if the switch and board are moved around slightly.

Now for construction:

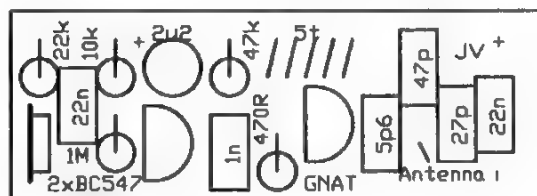
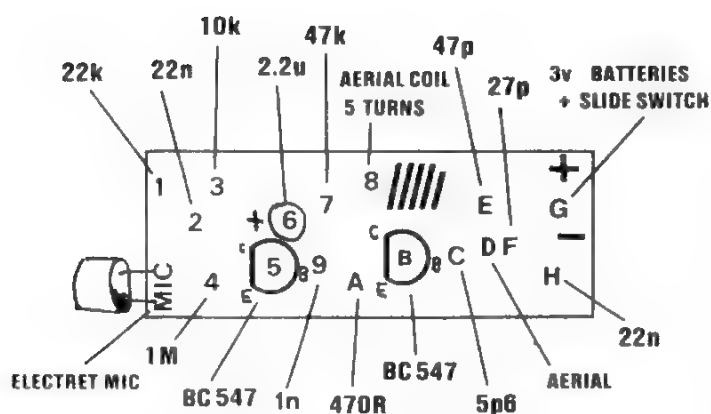
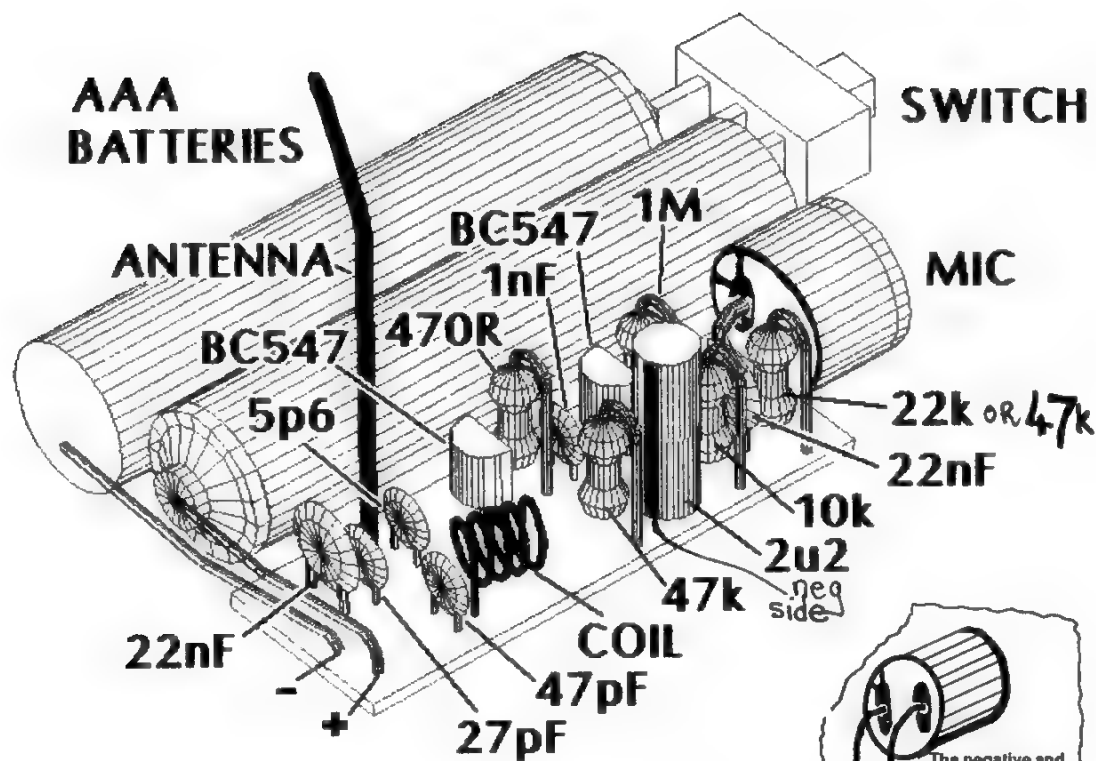
## CONSTRUCTION

We suggest that you buy a kit of parts as many of the components cannot be readily purchased, the coil is pre-wound and it is essential to build the project on the Gnat PC board.

The diagram on the next page makes it very easy to see where the parts are placed and shows how the capacitors and resistors are kept close to the board so that the leads do not alter the capacitance and impedance of the circuit.

## PARTS LIST

- 1 - 470R (yellow-purple-brown-gold)
- 1 - 10k (brown-black-orange-gold)
- 1 - 22k (red-red-orange-gold)
- 2 - 47k (yellow-purple-orange-gold)
- 1 - 1M (brown-black-green-gold)
- 1 - 5p6 ceramic marked as 5.6
- 1 - 27p ceramic marked as 27
- 1 - 47p ceramic marked as 47
- 1 - 1n ceramic marked as 102
- 2 - 22n ceramic marked as 223
- 1 - 2u2 PC mount electrolytic
- 2 - BC 547 transistors
- 1 - mini slide switch SPDT
- 1 - electret mic insert
- 2 - AAA cells
- 1 - 5 turn tinned copper wire coil
- 1 - 170cm antenna wire
- 1 - GNAT PC BOARD



Before starting, you should put the parts on the layout diagram opposite and make sure everything is included. Use the 47k for the microphone we have supplied. If you want greater sensitivity, use 22k.

Fit one part at a time and push it firmly onto the board. Bend the leads slightly so that the component stays in place and cut them so that 2mm is available for soldering. Solder the leads quickly and cleanly, making sure that new solder is added to the joint so that the connection is bright and shiny.

The transistors must be fitted so that they cover the outline on the board, the electrolytic must be fitted so that the negative stripe on the side is as shown on the diagram and the microphone is placed with the negative lead near the edge of the board.

When everything has been fitted, connect the batteries, switch and antenna. Make sure the turns of the coil do not touch each other and you are ready to try it on a radio. Switch the unit on and tune your FM receiver to the low end of the band. It should come through loud and clear.

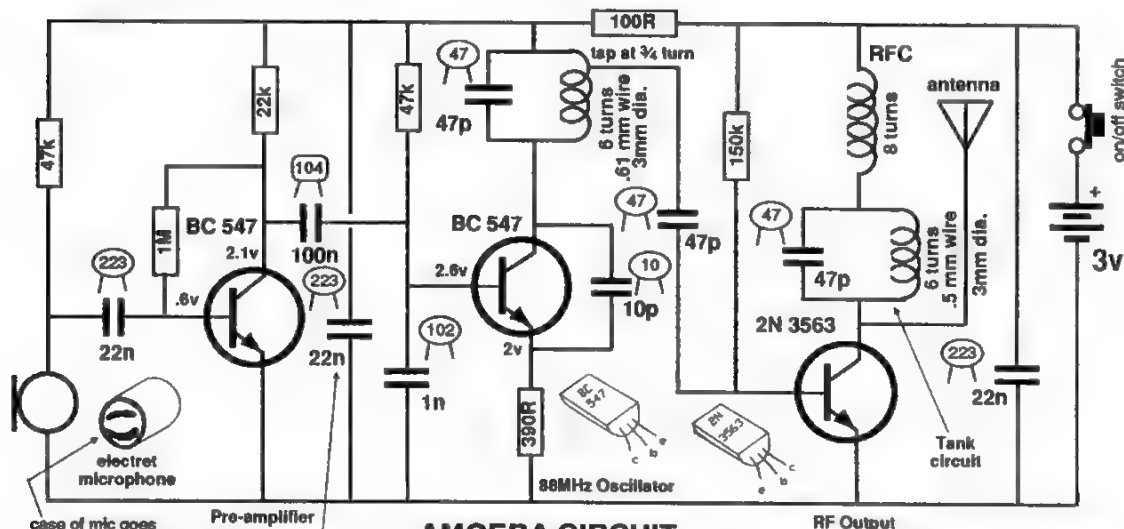
Fit it into a matchbox or other similar case and the project is complete.

# THE AMOEBA

Our 400 metre BUG. How far can you transmit on 10 milliwatts!

## Parts & PC Board

The LED Power Meter is needed to peak the output of this bug



## AMOEBA CIRCUIT

needed and eliminating things that didn't work.

### THE TUNED CIRCUIT

The effectiveness of the tuned circuit can be seen by the range we gained over the ANT or original FM Bug. Without any increase in current or supply voltage, we have increased the range four-fold. The only cost we had to pay was the stability of the output. The Amoeba is not as stable as the Ant and it cannot be handled or moved without affecting the frequency slightly.

It's designed to be placed in a location and left to transmit. To get the maximum energy out of the circuit, the TANK CIRCUIT must be tuned (peaked) to exactly the same frequency as the oscillator and the output transistor should be an RF type. That's why we have chosen a 2N 3563. It's about the only suitable, low-cost, type on the market.

On top of this, it is an advantage to include an RFC in the output to improve the narrowness of the transmission. (All the units we sell in made-up form have this included and are available for \$50.00. Refer to the list at the back of this issue.) It's an interesting exercise to compare the Amoeba with the Ant and determine where the extra output energy is coming from.

You can see the difference between the two circuits and when you read the accompanying notes, you will see how and

At first, the thought of producing a bug that would transmit 400 metres sounded far fetched. If you consider a circle of radius 400 metres, the area enclosed is quite considerable.

To send a signal over this range is quite an achievement and when we first started designing mini transmitters, we had no idea of what we would achieve. Some of the first devices went 50 metres, then 100, and then 200 metres.

We got stuck at 200 metres because, to double the range, the power must be increased four-fold. We were already at the limit of BC 547 transistors and did not want to go into high power designs.

So we let it rest for a while.

Some time later the thought arose that the output stage could include a tuned circuit to improve the performance and after some experimenting it was found it did in fact improve the output enormously.

After a few field tests the range had past the 300 metre mark and was approaching 400 metres.

Thus the AMOEBA was born.

It is an upgraded version of the ANT and although it appears that only a few components have been changed, it represents hundreds of hours of experimenting - working out what was

### PARTS LIST

- 1 - 100R (brown-black-brown)
- 1 - 390R (orange-white-brown)
- 1 - 22k (red-red-orange)
- 2 - 47k (yellow-purple-orange)
- 1 - 150k (brown-green-yellow)
- 1 - 1M (brown-black-green)
- 1 - 10p ceramic
- 3 - 47p ceramics
- 1 - 1n ceramic (102)
- 3 - 22n ceramics (223)
- 1 - 100n monoblock (monolithic) (104)
- 2 - BC 547 transistors
- 1 - 2N 3563 transistor
- 1 - 6 turn .61mm tinned copper wire 3mm dia coil
- 1 - 6 turn .5mm enamelled wire 3mm dia coil
- 1 - 8 turn .5mm enamelled wire 3mm dia coil
- 1 - electret microphone
- 1 - mini slide switch
- 2 - AAA cells
- 1 - 170cm antenna wire

### 1 - AMOEBA PC BOARD

why the tank circuit is more efficient than a load resistor. Although the tank circuit consists of only two components, we have written more than three pages on its operation. It's so brilliant that it would take even more than this to explain fully and when you visualise how the two

items work when placed together, you can appreciate the magic of electronics.

To us, the construction is fairly simple and straight-forward but if this is your first project in this field, I suggest you try the ANT as it is considerably simpler to construct and tune.

Some of the aspects of construction will be new to many readers, especially the tapped coil and the close parts layout but this is the sign of a professionally laid-out board and you must keep the circuit as tight as possible when you are working in the Mega-hertz range.

The tapped coil is common in radio work and is a very effective way of coupling two stages. It turns the coil into an auto-transformer in which the turns ratio of the whole coil compared to the single output turn provides a current gain of more than 6:1.

#### BUYING A KIT

I cannot stress too strongly, the need to purchase a kit. It is almost impossible for you to make your own PC board with tinned trackwork and a fully detailed overlay for less than the price we are selling them for. This is because we get them made 1,000 at a time on an automatic 3-head drilling machine and you could never compete with mass-production.

On one of the early CAD boards we placed the RFC around the wrong way and the output was reduced enormously. The simple mistake of having the tank coil and RFC positioned so that the magnetic field of each interacted to oppose each other took quite a while to diagnose.

Also the size and spacing of the coils is critical as is the wire gauge as well as the coil diameter and the number of turns.

This has all taken many hundreds of experiments to get the optimum size and shape and it all looks so obvious when it's finished.

If you want your project to work as good as the one we have described, the characteristics of everything must be identical to ours.

If you like experimenting, you should build a kit first, then you can experiment with another set of parts and make all the changes you like.

But let me stress, I think we have achieved the optimum performance and I don't think you will do any better. But don't let that deter you. Winning the lottery is nigh impossible and yet millions try their luck every week.

But that's getting off the track. First things first.

The Amoeba is only slightly more complex than the ANT in construction, but considerably more complex in peaking. The Ant needs no peaking at all but simply an adjustment of the oscillator

coil to get the desired frequency. The Amoeba requires additional skill in peaking the tank circuit to get maximum output.

This is done with the aid of a peaking meter (or peaking circuit) we call the LED Power Meter. It is made up of two diodes, two capacitors and a LED with resistor, connected to a multimeter set to a low voltage range. It is a very simple circuit that can be made in a couple of minutes and connected to almost any multimeter, in place of the leads.

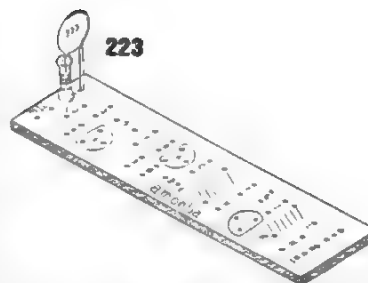
It's so simple yet so necessary in RF work. It's an RF power meter for very low outputs and although it is not calibrated, it works very well.

You will learn that the output of a transmitter is dependent on the effectiveness of the antenna and unless it is long and straight and away from any metal objects, the output will not be as good as expected.

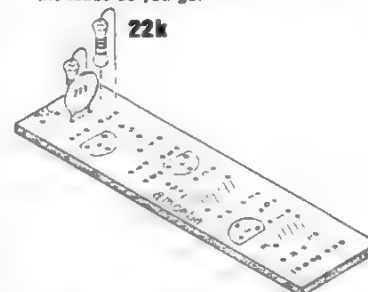
#### CONSTRUCTION

The PC board shown in the step-by-step guide on the following pages is our original board. We now have a CAD board with everything clearly identified on the top and you will have no trouble fitting the components.

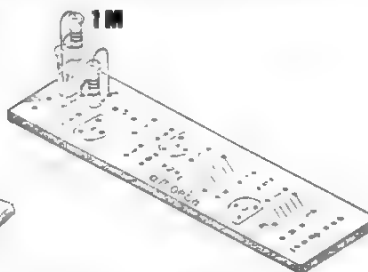
JUST USE THESE INSTRUCTIONS AS A GUIDE as everything is correct up to the RFC coil. The original board did not have an RFC but the CAD board has it included near the end of the board, beside the 22n.



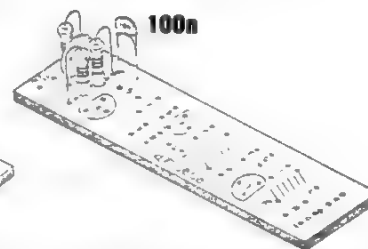
The next component is a 22n ceramic (223 marked on the body). It fits down holes marked '2' on the PC. It can be placed either way around and is soldered quickly so that it doesn't get too hot. Clip the leads as you go.



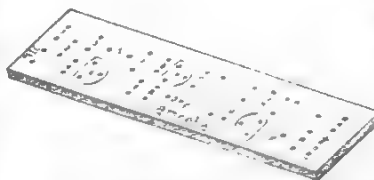
Next is a 22k (red-red-orange) resistor. It fits down holes marked '3' and is soldered quickly. The leads are cut off close to the board after it has been soldered.



The next component is a 1M (brown-black-green) resistor and is fitted as shown, into holes marked '4'. Solder quickly and cut the leads as before.



Next is a 100n monoblock. It is identified by 104 on the body. It is very small and goes down holes marked '5' on the PC.

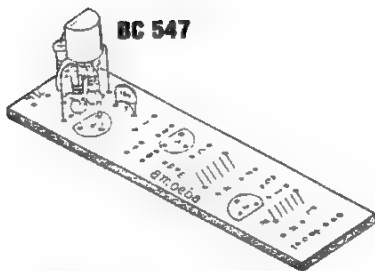


22k

**Inspect the Board.** It has numbers and letters to identify each component. Make sure all the holes are drilled and unblock any holes that are blocked with solder by touching with a hot soldering iron. This will open up the hole.

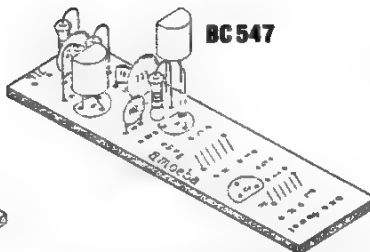


The first component to add is a 22k (red-red-orange) resistor. Bend one lead over and fit the two leads down the holes marked '1' so that the resistor touches the board. Solder it quickly in position.



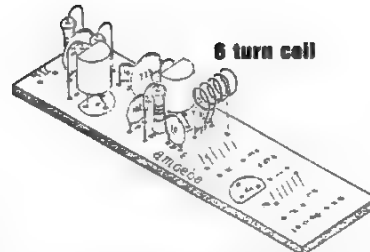
**BC 547**

Next fit a BC 547 transistor so that it is level with the top of the 1M resistor. It goes down holes marked '6' so that the flat on the body matches up with the flat on the overlay.



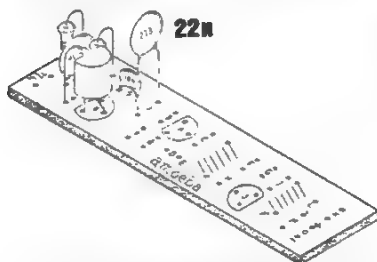
**BC 547**

The second BC 547 transistor is now added to the board. It fits down holes marked 'A' and soldered quickly as before so that it doesn't get too hot.



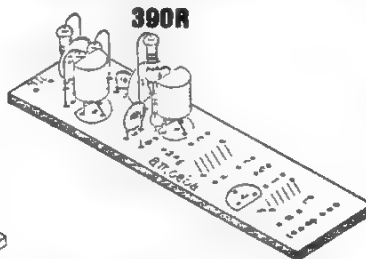
**6 turn coil**

The 6 turn tinned copper wire coil is next and is fitted down holes marked 'E.' The turns should be evenly spaced. Solder the leads and trim off neatly against the board.



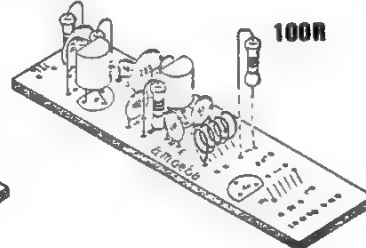
**22n**

Next fit a 22n ceramic into holes marked '7.' Press it against the board and solder quickly.



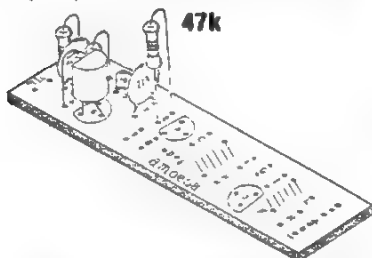
**390R**

The 390R (orange-white-brown) resistor is next and fits down holes marked 'B'. Keep it pressed against the board as before and solder neatly. Cut the leads off.



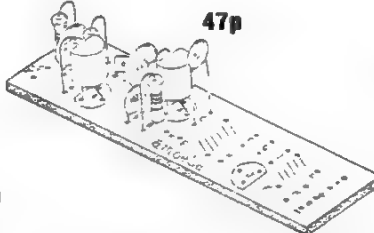
**100R**

Next fit the 100R (brown-black-brown) resistor into holes marked 'F' and solder as before.



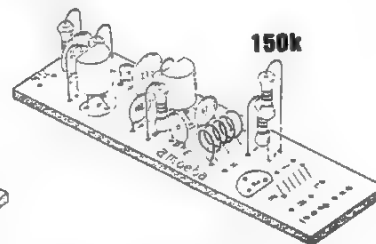
**47k**

Next fit a 47k (yellow-purple-orange) resistor down holes marked 'B' and solder quickly as before.



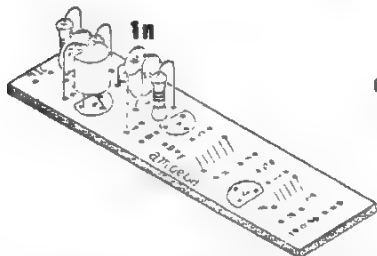
**47p**

Next fit a 47p ceramic into holes marked 'C.' The capacitor will be marked 47 on the body and solder quickly to prevent overheating.



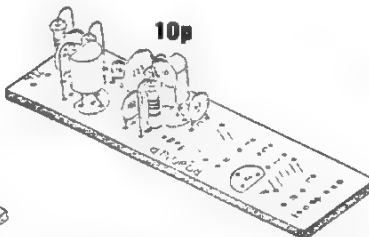
**150k**

The 150k (brown-green-yellow) resistor is next. It is soldered into holes marked 'G' and the leads cut off.



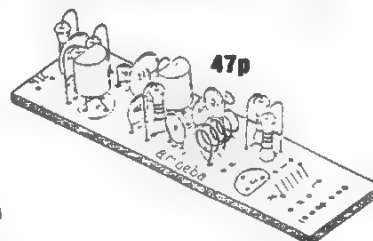
**1n**

The next component is a 1n (marked as 102) ceramic capacitor. It fits down holes marked '9' and soldered quickly.



**10p**

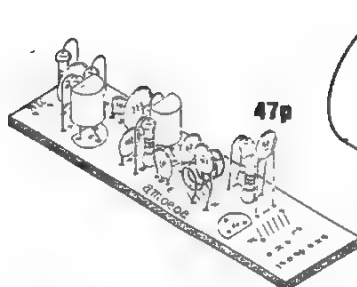
The 10p ceramic fits down holes marked 'D' and should be kept away from the area allocated to the coil.



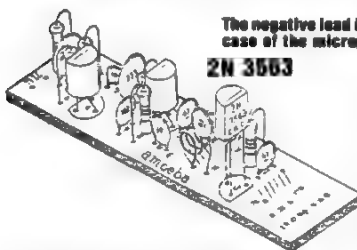
**47p**

The next component is a 47p capacitor. One end is soldered to the top of the first turn of the coil and the other end fits down hole 'H.' If possible, try to connect to the 3/4 turn of the coil as this will give better output. See photo on next page.

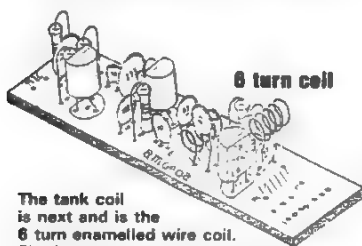




Next is a 47pF capacitor that fits into holes marked 'I'. Push it firmly against the board and solder quickly.



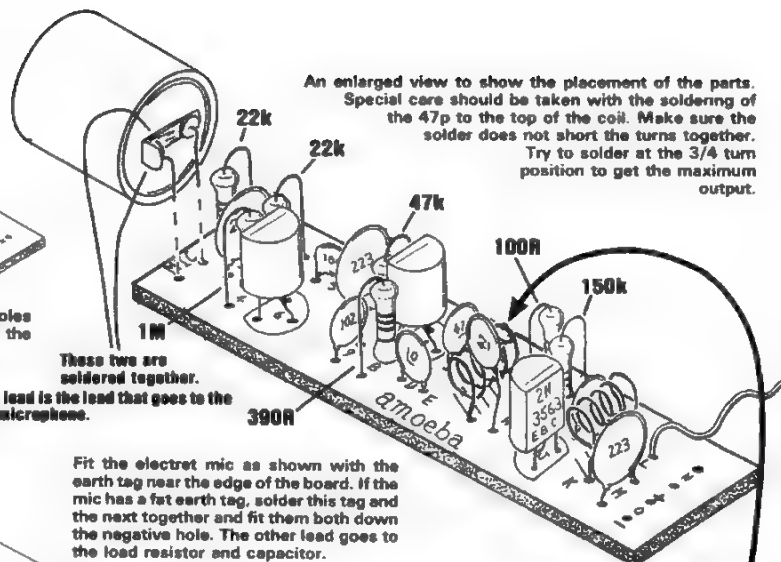
The final transistor is a 2N 3563. It fits down holes marked 'J' and pushes neatly up to the board and soldered quickly to prevent over-heating.



The tank coil is next and is the 8 turn enamelled wire coil. Firstly remove the insulation from about 1/2cm from each end by heating the wire with a soldering iron that has been tinned with solder. Refer to the diagram for the lead length to see what we mean. After a few seconds the insulation will burn away and the solder will 'take.' Don't breathe the fumes or let them get in your eyes. Fit the coil down the holes marked 'K.' Solder the leads and cut them off.



The antenna can be left to test and is fitted down hole marked 'L'. The next component to add is the 22nF ceramic (marked 223) and fits down holes marked 'M.' Solder in place and trim the leads.

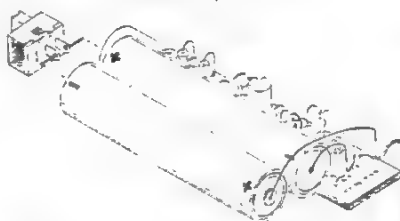


An enlarged view to show the placement of the parts. Special care should be taken with the soldering of the 47p to the top of the coil. Make sure the solder does not short the turns together. Try to solder at the 3/4 turn position to get the maximum output.

These two are soldered together.

The negative lead is the lead that goes to the case of the microphone.

Fit the electret mic as shown with the earth tag near the edge of the board. If the mic has a fat earth tag, solder this tag and the next together and fit them both down the negative hole. The other lead goes to the load resistor and capacitor.



Solder the switch to the batteries. The positive end of one battery goes to the positive on the board via a length of hook-up wire and the negative lead goes to the negative on the board via tinned copper wire.



A close-up of the 47pF soldered to the 3/4 turn position on the oscillator coil.

Antenna is left to LAST. (after PEAKING).

You should now refer to the photos and note the position of the 8 turn RFC at the end of the board. Scrape the enamel off the leads and tin them before soldering the coil to the board.

This completes construction and you are now ready for the tuning operation and peaking. This involves selecting a frequency on which you will transmit that is away from any radio stations and peaking the circuit to get the maximum output.

## TESTING AND PEAKING

You may think our method of testing a transmitter is back-to-front because we start at the output and work towards the front end. But when you look at it more closely, you will see why.

Once you have the output stage working, you have a starting point and from there the procedure is fairly straight-forward.

The output of the transmitter consists of two parts. The base part is called the 'carrier' and this is a constant frequency. If we are transmitting at 100MHz, it is a 100MHz frequency. Added to this is the audio component and this causes the base frequency to increase and decrease by an amount equal to the audio frequency being picked up by the microphone.

This audio tone FREQUENCY MODULATES the carrier and this gives the

term FM transmission.

We use this knowledge to fault-find the project. Our first concern is to be able to detect the carrier. This is picked up on an FM radio as a 'dead spot' or 'clear spot' on the dial when the transmitter is on. When the transmitter is turned off, the background noise appears.

The carrier is produced by the oscillator



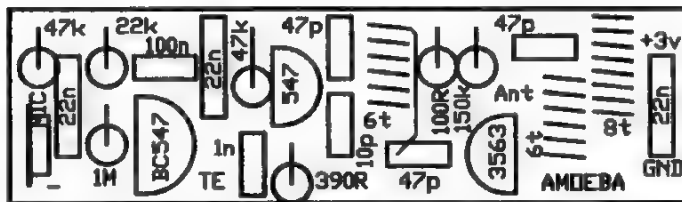
Trackwork for the Amoeba

stage (the BC 547) and the linear amplifier (the 2N 3563) will transfer this frequency to the antenna with increased driving power. When we detect a carrier, we prove that both stages are working. If a dead spot is not heard, you should firstly assume the frequency of transmission is off the FM band.

To adjust the transmitter, all you need do is stretch the turns of the oscillator coil (making sure they do not touch each other if bare tinned copper wire is used). Tune across the entire band on the FM radio, looking for a silent spot.

The bandwidth of the transmitter will be quite narrow and it will be necessary to sweep the band fairly slowly. If nothing is heard, go over some of the simple faults such as making sure the project is ON, the radio is on the correct band (88MHz to 108MHz), the radio has an antenna connected and no metal objects are near the transmitter.

You must detect a carrier before progressing any further. This is the starting point and no other



Amoeba overlay showing the position for all the components.

sections can be tested until this is successful. Unless you have a 100MHz CRO, there is no other way to see if the project is transmitting.

This is not exactly true as another solution is to make a second model. If the second model works successfully, (and I see no reason why it shouldn't), you can use it to physically check the spacing of the coil, placement of the parts and the position on the FM band, to see why things are not coming through on the first model. When a dip is heard, you are half-way home.

In fact you are 90% home. The rest is down-hill. The next step is the testing of the audio stage or stages. Although the project contains one audio stage, we can consider the microphone to be a stage since it is an active device containing a FET transistor.

If either the microphone or pre-amplifier stage does not work, you will only get a carrier output. Make sure the voltage on the microphone is at least 50mV and the collector of the pre-amplifier is at least .8v.

If it is less, the transistor may be saturated and if it is 3v, the transistor will

not be conducting. Check the base voltage also. It should be .65v. If this fails to locate the fault, you can use almost any CRO to pick up the waveform at a number of locations on the board, around the audio section.

By whistling into the microphone and picking up the waveform at the output of the mic (at the point where the load resistor connects to the mic), you will be able to see the output of the microphone.

Next, pick up the waveform at the other end of the coupling capacitor and note that some of the amplitude has been lost. This point is also the base of the audio transistor and you can determine the gain of the transistor by comparing the output with the input. The gain should be between 50 and 100.

The output is injected into the base of the oscillator stage via a DC blocking capacitor and this is where the CRO capability finishes. You will need a 100MHz CRO from now on. You should adjust the oscillator coil to a frequency away from a radio station and this is generally at the very bottom of the band. Once the circuit is working successfully, the final part is to peak it by adjusting the coil on the tank circuit.

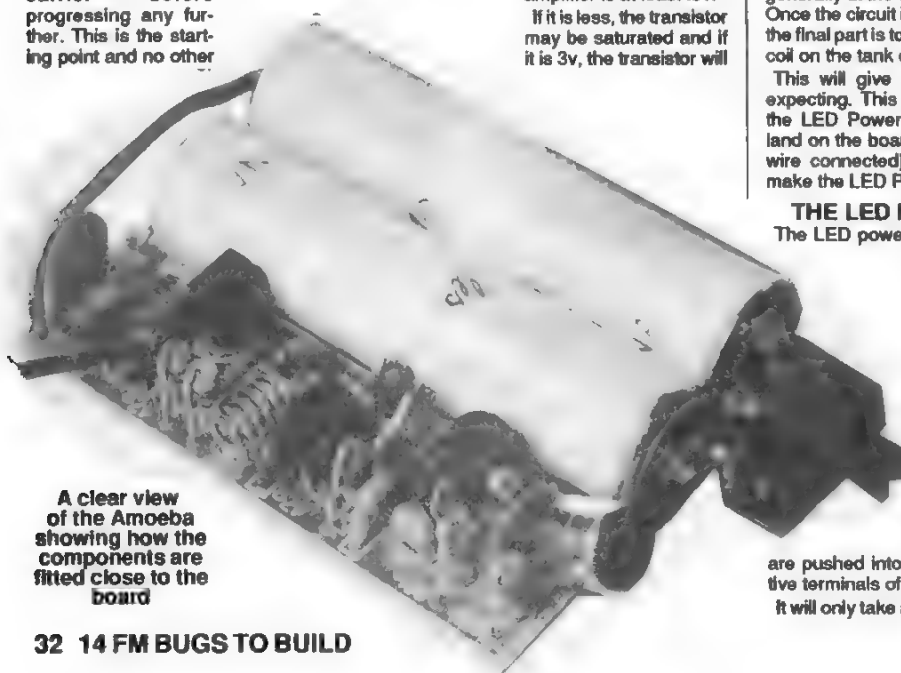
This will give the range you will be expecting. This is done by connecting the LED Power Meter to the antenna lead on the board (without the antenna wire connected). But first we have to make the LED Power Meter.

#### THE LED POWER METER

The LED power Meter is a simple RF detector using diodes to charge a capacitor. The voltage developed across the capacitor is shown on a multimeter set to a low voltage range. The circuit is soldered together without the need for a PC board, as can be seen in the diagram above and the two paper clips

are pushed into the positive and negative terminals of the multimeter.

It will only take a few minutes to put this



A clear view of the Amoeba showing how the components are fitted close to the board

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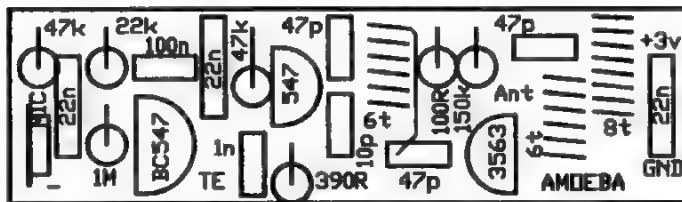
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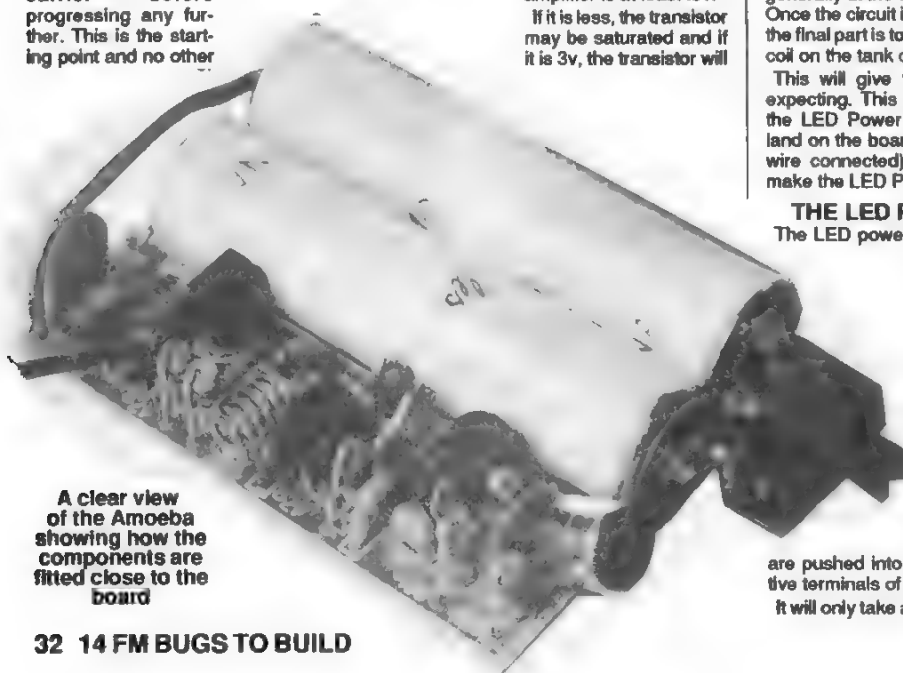
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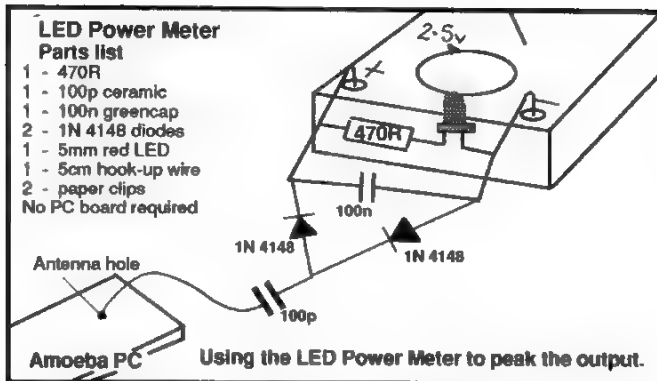


A clear view of the Amoeba showing how the components are fitted close to the board

## LED Power Meter

### Parts list

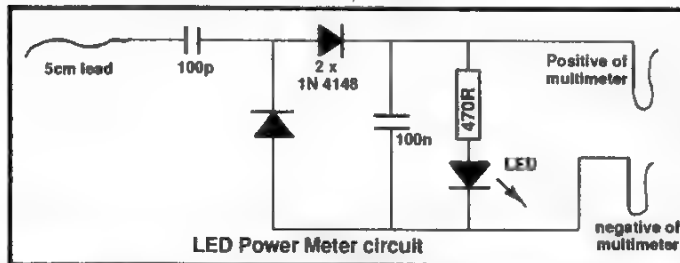
- 1 - 470R
- 1 - 100p ceramic
- 1 - 100n green cap
- 2 - 1N 4148 diodes
- 1 - 5mm red LED
- 1 - 5cm hook-up wire
- 2 - paper clips
- No PC board required



circuit together and you are ready for the Peaking operation. The LED Power Meter has two ranges. The low range measures output voltage up to about 1.5v and at this level the LED does not come on as it requires at least 1.7v for it to turn on. Thus the LED does not put any load on the circuit so you can measure very low outputs such as the

oscillator stage.

As the voltage rises over 1.7v, the LED starts to turn on and thus the circuit turns onto a POWER METER to measure milliwatts of output power. This power is indicated by the illumination of the LED and since a LED can't lie, you can compare the output of one transmitter with another.



LED Power Meter circuit

## USING THE LED POWER METER

Connect the 5cm wander lead to the collector of the oscillator transistor on the Amoeba board and turn the project OFF.

The lead of the LED Power Meter will act as an antenna, so place a radio nearby and tune it to about 88.5MHz or somewhere at the low end of the band. Move the turns of the 6 turn oscillator coil either together or stretch them apart until a feedback whistle is picked up by the radio. This is the frequency of transmission.

When the turns are pushed together the frequency decreases and when moved apart, the frequency increases.

Now place the wander lead from the LED Power Meter onto the antenna point on the board and move the turns of the 6 turn tank coil either together or apart until the reading on the Power Meter is a maximum.

You must not use any metal objects near the coil as you do this as this will upset the reading.

The best item to use is a match or plastic knitting needle as you should keep your fingers and hands away from the coil while adjusting it.

The circuit will peak to about 1.25v to 1.65v (the voltage will depend on the quality of the transistors). Once you are satisfied the output is a maximum, remove the LED Power Meter and solder the antenna lead to the board.

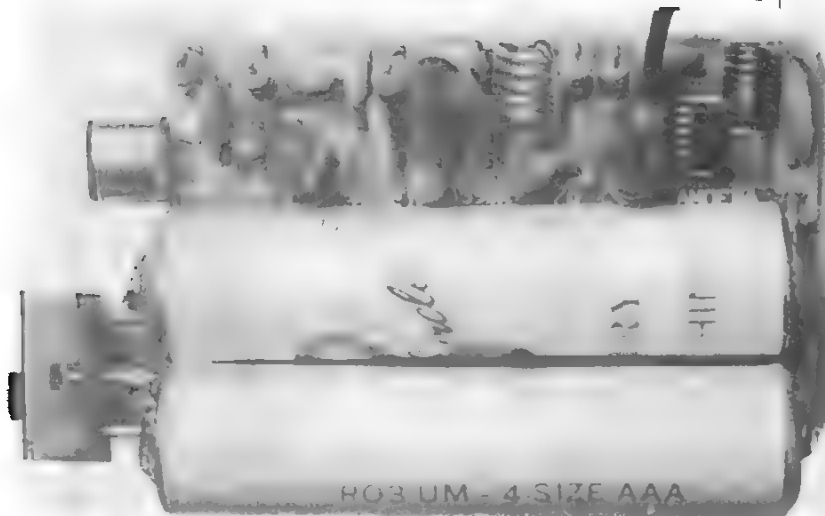
Move the radio a short distance away and tune across the band to make sure the output is only coming through at one spot on the dial.

If you get two spots, the frequency of the oscillator and tank circuit do not coincide. Go back and adjust the tank coil until the two frequencies are the same.

When this is done, the project will be "peaked" and will deliver the maximum output.

The project is now ready to fit into a Tic Tac box. The ON/OFF switch can be operated by opening the lid and switching the bug on. It does not matter if the lid is open or closed, the microphone will pick up the faintest sounds in a room and transmit them to an FM radio up to 400 metres away. Of course, this will depend on the positioning of the antenna and the quality of the radio. The antenna should be stretched out and placed over a high shelf etc so that the signal has an opportunity to radiate effectively.

Do a bit of experimenting and you will be very impressed with the performance.



Completed Amoeba project with batteries and switch attached

# THE TANK CIRCUIT

By now you will be aware that the only major difference between the ANT and the AMOEBA BUG is the TANK CIRCUIT.

This circuit consists of a 6-turn coil in parallel with a 47pf capacitor. It looks to be a minor improvement and you may think it will make little difference to the performance of the circuit. But you will be wrong!

It makes an enormous difference and the way these two components function is very impressive.

In fact the theory behind the way they function is so complex that it could take pages to fully explain. The reason is that they are **RESONATING** at the same frequency as the oscillator circuit and this means that the voltage and current flowing in and around the tank circuit is completely different to what you may think

When a coil and capacitor are resonating a number of new terms are encountered and the voltages and currents are considerably higher than the rail voltage and the supply current.

That is why it is so different. In our testing, we found the output was only a few millivolts when the circuit was non-resonant (i.e. with a 330R load resistor) and increased to over 1200 millivolts when it was **TUNED**.

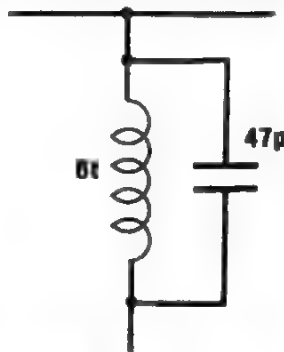
Tuned means resonating (this term is very similar to the word oscillating) and to get the parallel circuit to resonate the turns of the coil must be compressed or expanded until the output power is a maximum. Our simple power meter is connected to a multimeter and will indicate when the maximum power is being delivered to the antenna. A fairly simple device, but it works.

The phenomenon of resonance makes the output stage considerably more efficient than using a load resistor as the same energy is being taken from the battery but more is being transferred to the antenna. Very little is lost in the tuned circuit

When we talk about a resonant circuit we mean a circuit that is resonating and more specifically a circuit that is receiving pulses of energy arriving at the precise moment to keep the circuit swinging back and forth exactly like pushing a swing at the correct instant.

If we take the swing example, it can be pushed such that it swings back to a position that is higher or further up the arc than the pusher! You have possibly done this many times.

Exactly the same can happen in a resonant circuit. The voltage developed across it can be as much as 100 or even 300 times greater than the applied voltage. This means that a 12v circuit could see a voltage of 3600v across the capacitor (and coil)!



This is the tank circuit we are talking about - A 6 turn coil in parallel with a 47pf capacitor.

This is theoretical and applies to an unloaded resonant circuit. As soon as you connect it up, and ask it to deliver, the output drops to between 2 and 100. Even so, you can see that a parallel combination is making the output stage two or more times more efficient than a purely resistive load.

We will go into the mechanics of how a resonant circuit operates in a moment. But first let's look at the consequences of producing a higher voltage.

At the transmitted frequency, the aerial is seen as a resistive load plus a small amount of inductance and capacitance. But basically it is resistive and has such a low value that the signal finds it very easy to flow into the aerial.

This means energy is lost from the circuit in the form of electromagnetic radiation. When the voltage at the

aerial is increased it will allow a higher current to flow into the antenna and thus the output power will increase.

This means that when a tuned circuit produces a higher voltage, more energy will flow into the aerial and this gives us the improved performance we have called the AMOEBA.

In terms of increased efficiency, our output power detector circuit showed an enormous increase as mentioned previously and when related to range, our field tests showed this to be increased at least double, even under the worst conditions.

## THE Q FACTOR

This leads us to another very important term that relates to the efficiency of a tuned circuit. It's called the **Q** factor.

There are a number of ways of defining the Q factor but basically it is the ease with which a resonant circuit oscillates. If we place a coil and capacitor in parallel and put them in the middle of our work bench, nothing will happen. But if we connect a wire to one end, chances are the circuit will resonate.

This is because the wire will pick up radio signals and one of the signals may be the exact frequency of the tuned circuit.

If you decrease the value of the coil (open up the turns or remove a turn) and increase the value of the capacitor, the circuit will resonate at the same frequency but the output will not be as high because the energy from the coil will not be as much as before.

Thus there is an optimum value of inductance/capacitance for any given frequency and this is called the optimum L/C ratio.

The signal picked up by the tuned circuit will be very small and will correspond to a person pushing a swing minutely, at exactly the right time to keep it swinging.

All the other frequencies will be similar to the swing being pushed at the wrong time and in the wrong direction and will cancel each other out and have no effect on the final amplitude.

As soon as you try to measure the amplitude of the voltage in a tuned circuit you put a load on it and the Q drops enormously. Thus it is very difficult to observe an unloaded tuned circuit



The second amazing fact is a high Q circuit will respond to only 1 frequency and as the Q factor is lowered (through loading or poor selection of coil and capacitor values) the 'frequency-band' increases.

Thus it is important to have a high Q circuit, so that only the required frequency is produced. This is called selectivity and makes the bug transmit all its energy on a very narrow band.

The tank circuit must be fine tuned to match the oscillator frequency and this is done by adjusting the spacing of the turns of the coil.

The exact set-up procedure is covered in the main part of the article and you will need a detector circuit and multimeter to peak the output.

#### HOW THE TANK CIRCUIT WORKS

We have said the tank circuit produces a voltage greater than the supply voltage. But how does this happen?

To understand this you need to know about collapsing magnetic fields. When an electro magnet is switched off, the collapsing magnetic field produces a voltage in each of the turns that is in the opposite direction to the applied voltage and because the magnetic field collapses very quickly the voltage can be as much as 100 times or even higher than the applied voltage.

Take the example of a buzzer, relay or spark coil in a car.

If you connect a buzzer to a power source, you will see a spark between the points. This is the high voltage jumping the air gap as the points open. The same will happen if you connect a relay to a battery and touch the two ends of the coil with wet fingers. You will feel a tingle as soon as the relay is removed from the battery

This is due to the collapsing magnetic field producing a voltage in the winding and this can be as much as 80 to 100 volts. This time you feel the voltage instead of seeing it

The size of the voltage will depend on the number of turns and the amount of magnetic material in the core but it is important to note that the voltage is higher than the supply.

If we transfer this knowledge to the tank circuit, we see how the higher voltage is produced. It comes from the inductor.

But how does the circuit resonate and what does 'resonate' mean?

Resonate means oscillate at a frequency that is natural (characteristic) for a given value of inductor and capacitor.

If we connect a coil and capacitor in parallel and place them across the terminals of a battery, the capacitor will be in an uncharged state and will charge up. The current will also produce a magnetic field in the coil but let's neglect this for the moment.

When the supply is removed, the charge from the capacitor will flow into the coil and produce a magnetic field. After a short period of time the capacitor will become discharged and unable to maintain the field.

At this stage the field collapses and produces a voltage in each turn that is of opposite polarity and higher than before.

The energy in the collapsing magnetic field is converted to electricity and this charges the capacitor.

The energy will be less than before due to losses in the system and the capacitor will receive only a fraction of the original. However some WILL be returned.

If we provide a transistor arrangement that turns on at the precise instant when the capacitor is charging, it will be able to add energy and top-up the capacitor. This will give us the same amount of energy as we had at the start of the cycle.

This is what happens in the tank circuit. The transistor injects energy into the capacitor and turns off. But the antenna draws energy out of the circuit and to see the effect it has we need to go back to the beginning of the cycle.

Let's start at the instant when the transistor turns ON. This action draws one end of the tank circuit low. The antenna sees this low potential and very little energy will be radiated but the 47pf capacitor will charge.

The next thing to happen is the output transistor will turn off. This is due to the 47p capacitor and works in this manner: The waveform from the oscillator circuit is only a maximum for a short period of time and once it starts to fall, it draws the 47p low and charges it for the next cycle. This action robs the base of the output transistor with turn-on voltage.

The result is the transistor turns OFF.

The 47p in the tank circuit delivers its energy to the coil and at the same time a very small amount to the antenna. This discharges the

capacitor and when the energy has almost been spent, the magnetic field starts to collapse.

We have seen what happens and now the higher voltage from the coil is sent back to the capacitor and antenna.

This high voltage sees the antenna as a low resistance and readily flows into it. Thus the returning energy is split between the antenna and capacitor.

Ideally most of the energy flows into the antenna and little into the capacitor so that when the transistor turns on, it needs a fair amount of topping-up.

The voltage appearing at the base of the antenna could be twice or three times the supply voltage and this represents the Q of the tank circuit.

The loading effect of the antenna will affect the Q of the circuit and to reduce the loading a small capacitor (10pf to 33pf) can be inserted in the base of the antenna.

As the Q is raised, the bandwidth of transmission is narrowed and the energy becomes concentrated on a narrower and narrower band.

The voltage on the antenna also increases and thus the range is improved.

There are optimum values for all this and it will take experimenting to get the best results.

The main point of the exercise is to see the advantage of the tank circuit and to realise that much less loss is incurred than with a load resistor.

The tank circuit DELIVERS to the antenna by converting the pulses of energy from the output transistor into a smooth waveform that is ideal for producing electromagnetic waves.

The diagrams on the opposite page can also represent the Q of the oscillator circuit or the Q of the tank circuit. They apply whenever energy is picked off a coil/capacitor combination.

As the coupling capacitor is increased (we have used 47p in the Amoeba), or the antenna load is increased, the pick-off will be greater but the Q of the circuit will decrease so you may not get any improvement. You have to experiment to get the best output.

The drastic lowering of Q means you are beginning to transmit on two different frequencies. This is obviously undesirable and the only way to avoid it is to use a radio to detect if one or two peaks are present.

A high Q circuit also introduces two other design factors. These are 1. The ratio of the diameter of the coil to its length and 2. the L/C ratio of the tuned circuit.

It's difficult to know where to start when designing a high Q circuit but if you begin with the coil, everything else will fall into place. This is because the inductance of the coil (or more accurately its efficiency) plays the most important role.

The efficiency is the amount of energy released, compared with the amount of energy inputted and this depends on many factors, one of which is the ratio of the diameter of the coil to its length.

Ideally the length should be between one and two times the diameter and this will allow the collapsing magnetic field to have maximum effect when cutting the adjacent turns.

The other factor **L/C RATIO** means the value of the capacitor must be chosen so that at the resonant frequency, the inductive reactance of the coil (in ohms) is equal to the capacitive reactance of the capacitor (also in ohms). This means the energy contained in the capacitor will be just the right amount that can be handled by the coil.

Wire size for the coil is not important, as such, but a fairly thick gauge will keep the turns in position whenever the project is handled and that's why it has been chosen.

The one thing that is important is the placement and type of capacitor. A ceramic capacitor has been used in the prototype and you should keep to this type as other types (such as mica or styro) have a different reactance value at high frequencies. Also it is important to keep the leads short (as shown in the drawings) as long leads on the capacitor or coil will alter the inductance value considerably.

After all, we are talking about pf (puff) values and microhenry values and a change of only a few per cent will take the operating frequency off the band.

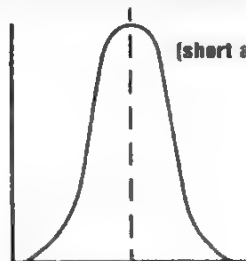


Fig 1(a): HIGH 'Q.'

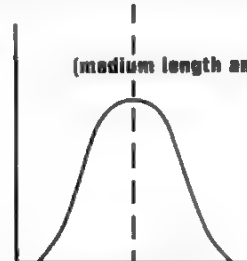


Fig 1(b): MEDIUM 'Q.'

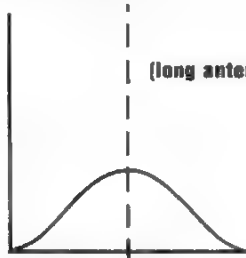


Fig 1(c): LOW 'Q.'

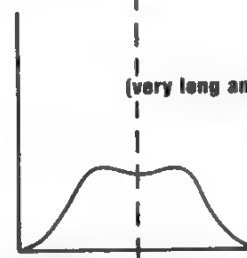


Fig 1(d): Double transmitting humps due to heavy loading effects.

### THE EFFECT OF ANTENNA ON Q OF A TANK CIRCUIT:

As the length of the antenna increases, the impedance and effective Q of the tank circuit decreases. Fig 1(a) shows the effective Q of the tank circuit when a short antenna is coupled to the output. This represents an antenna of about 2cm to 10cm long.

Fig 1(b) shows the Q when a medium length antenna is connected, such as 10cm to 30cm.

Fig 1(c). As the antenna is increased in length, the resonance curve becomes broader and the Q value decreases, however this is the optimum condition as the maximum amount of energy is being transferred to the antenna.

Fig 1(d). If the antenna is loaded (such as holding it with your hand), the resonance curve becomes even broader and double resonance humps develop with very poor energy transfer resulting.

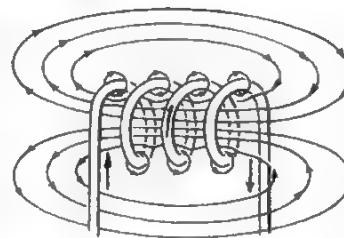
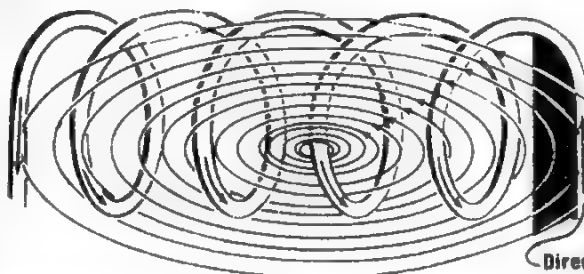


Figure 2 is a simplified diagram of the magnetic lines of force surrounding the oscillator coil when a current is flowing.

Use Flemings Right Hand curled fingers rule to determine the direction of flux (and thus the North Pole) when the direction of current flow is known.



Direction of current flow.

Figure 3 shows the action of the magnetic field expanding outwards from the centre of one of the turns and cutting the adjacent turns. This action is happening from every part of each turn and the number of lines would be too numerous to draw. It is this action between the turns that gives the coil its value of inductance.



the output.

The first thing to do is cut the board so that the microphone fits over the edge. Don't fit the microphone until last so that the leads are not fractured by movement.

Use the photos and diagrams on this page to help fit the components. Some parts are very easy to fit and these can be positioned first. This will leave vacant holes to help you position the rest of the parts.

The 47p that taps onto the 6 turn oscillator coil is soldered to the first turn (near the positive rail) as shown in the photo.

Keep everything close to the board so that the whole project will fit into a Tic Tac box.

The switch is fitted to the board with 3 short lengths of tinned copper wire and the top of the switch is kept as high as possible so that it can be turned on and off through the door of the Tic Tac box.

The 8 turn and 14 turn coils mount upright on the board and the 5 and 6 turn coils lay flat.

The last component to add is the microphone. The negative lead is the one that goes to the case of the microphone.

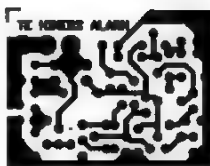
Clean the bottom of each 'N' cell with a file or sandpaper before tinning with a hot iron. They are then soldered together with tinned copper wire and soldered to the board.

This completes the assembly and the next step is to adjust the frequency to between 88.3MHz and 90MHz and peak the output. We have picked this band as it is the low end of the FM band and provides the best range. Don't go below 88.3MHz as some drift in the frequency may occur as the batteries get used up and we don't want the frequency to go off the band.

You won't have to worry about a clear spot on the band as there are very few stations in the country areas, where you will be using the alarm.

### PEAKING

Fit the peaker or LED Power Meter to the collector of the oscillator transistor and turn the unit on. A reading on the meter will indicate the oscillator is working and



Full-size layout of the PC board showing how small the board really is.

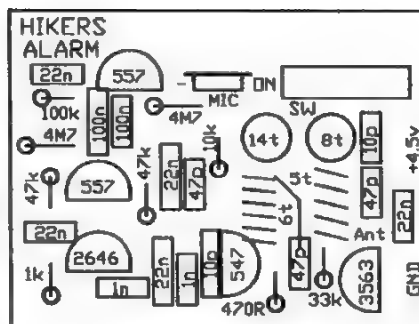
you should tune a radio to about 88.5MHz and put the radio about 3-4 metres from the project.

Squash or separate the turns of the 6 turn coil until you hear a beep in the radio and also a feedback whistle. Moving the turns apart will raise the frequency of transmission and squashing them together will lower it.

The Peaker circuit is simply used as an antenna at the moment and it is now transferred to the collector of the output transistor (2N 3563).

Without touching the tuning of the radio, move the turns of the 5 turn tank coil until the beep and feedback whistle are heard again.

This will make the oscillator and tank stages operate at the same frequency and you will notice the output of the



### ENLARGED VIEW OF THE HIKERS ALARM ARTWORK

circuit will increase when this occurs.

We now adjust the spacing of the RFC coil by watching the meter and noting when it has a maximum reading.

You may like to fit the antenna and test the circuit for range. The tank coil may need fine adjustment due to the loading effect of the antenna.

The circuit is now peaked and ready for last minute finishing touches.

It's a good idea to mark the "ON" position for the switch with red nail polish so that you can see when the circuit is ON.

### IF IT DOESN'T WORK

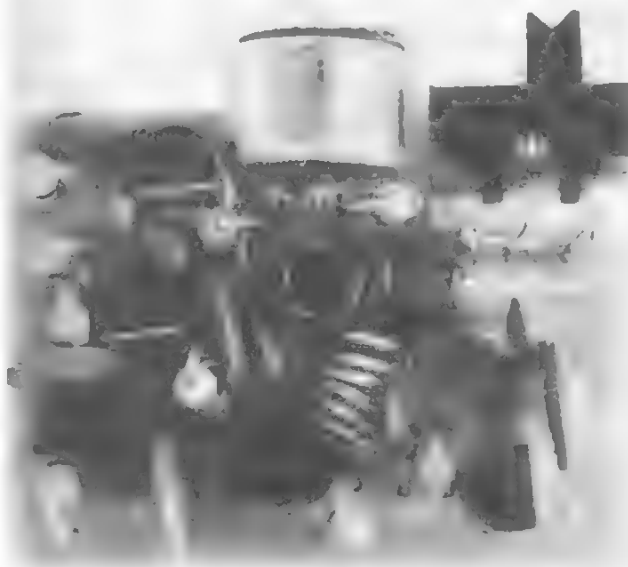
If the project doesn't work, you will have to work out where the fault is coming from by referring to the full article. Photocopies are available for \$2.00 as the original book has now fully sold out. There are 5 sections in this project and you must concentrate on one at a time. But before doing anything, read the article so you know how to approach the problem.

### THE CASE

The project has been designed to fit into a Tic Tac box and you should be able to fit the works neatly if you have followed our instructions.

The 3m antenna passes through a hole in the bottom of the box and is wound up neatly, ready for use.

Place everything into a zip top bag so that it won't get wet and it's ready for the next time you go for a hike.



Note: This is an old photo. The 10p is now mounted on top of the board and the overlay shows where everything goes.

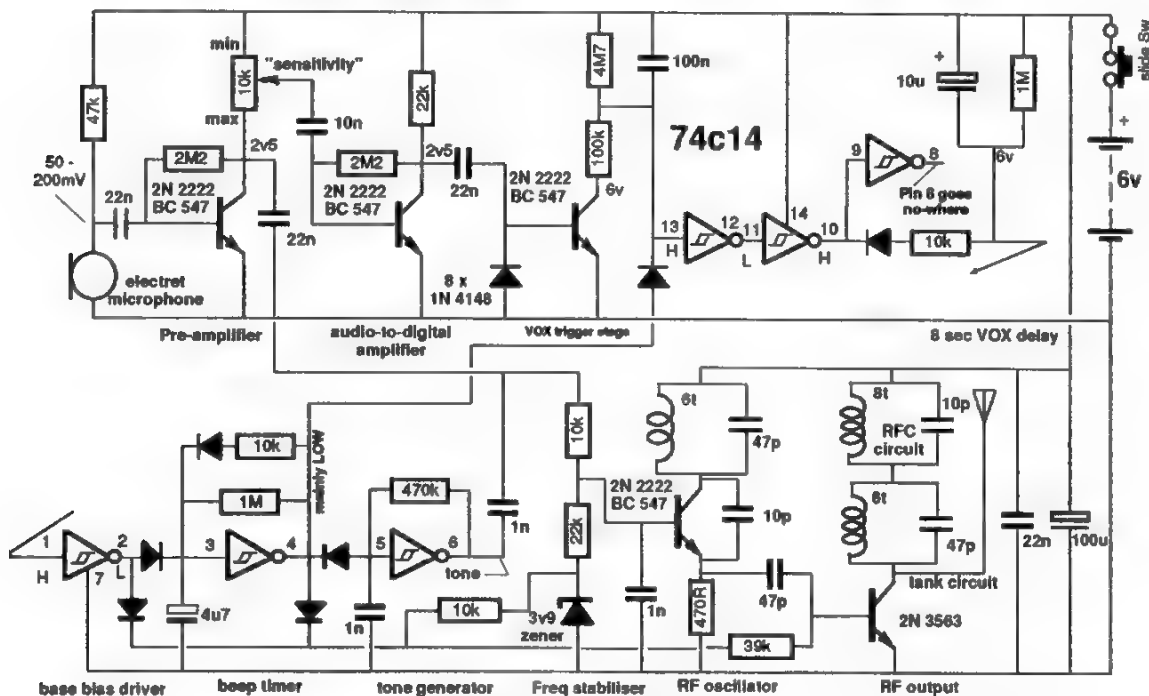
# VOX<sup>Mk IV</sup> with BEEP

VOX = Voice Operated Switch

Parts & PC  
PC board only

OUR LONG-RANGE VOICE-OPERATED FM BUG

LED power meter required to  
peak the bug:



## VOX Mk IV with BEEP

Note: DC voltages during beep mode

This VOX Bug takes over from our MkIII model and overcomes two slight problems that showed up when the MkIII kits went out for construction by our readers. This first improvement makes sure the beep comes through on the same frequency as the audio.

We also re-designed the circuit so that the oscillator was biased by a zener voltage. This provided a degree of stability so that the frequency was kept stable as the supply voltage fell during the life of the batteries.

The second improvement is extra sensitivity in the VOX section. We added a transistor (we called it the VOX trigger stage) after the analogue-to-digital stage to increase the waveform even further so that the bug turns on with a whisper at 3 metres.

If you haven't been following our series on FM transmitters you should read the article on VOX Mk III. It will bring you up to date with the development of these

### FEATURES

Range: about 1800ft - 600metres  
Current: .8mA on beep  
10-12mA on transmit  
Supply: 4 x AAA cells  
Battery life: 600-800Hrs  
Frequency range 88-108MHz  
Vox sensitivity: turns on with speech at 15ft (5 metres)

circuits and show you the order in which they were developed and our suggested order for building them.

We have already mentioned that FM is by far the most efficient way to transmit as a few milliwatts will produce a signal that will reach up to 1km with clarity as good as any commercial FM station.

Keeping this in mind we consider this circuit to be the most advanced on the kit market.

It offers the advantage of consuming very little current (about .8mA) when in

the listening mode and provides a homing beep so you can tune into the frequency at any time and be able to pick it up when the bug turns on.

This means the transmitting current (10 - 12mA) is only drawn when noises or voices are detected and the life of the battery can be increased by some 800% or more.

By careful peaking of the circuit and placement of antenna, you will be able to get an output with a coverage of 1km or more.

Its uses can extend to protection of house and property, cars, equipment, factories and almost anything you wish.

We have found that nothing is safe from prying eyes and itchy fingers. We have had thousands of dollars worth of goods stolen and had to increase our security considerably.

The VOX IV is one of the devices we use and have added it to our surveillance range in made-up form, for those



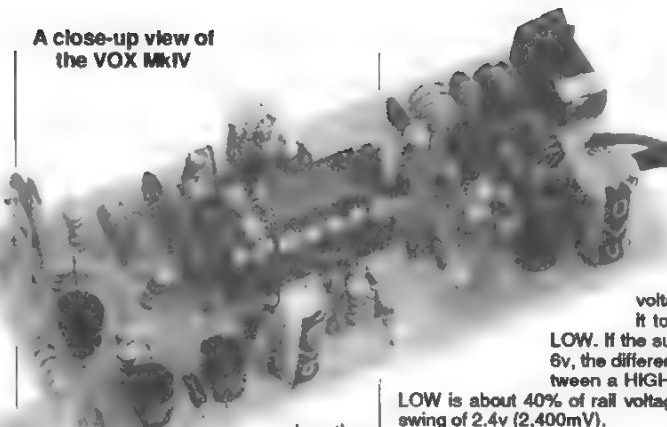
who are not able to put things together themselves.

## HOW THE CIRCUIT WORKS

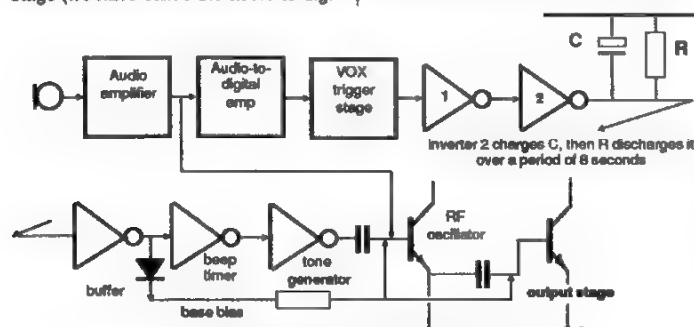
The circuit picks up sounds with a sensitive electret microphone and passes the signal to a common emitter amplifier using a 2N 2222 or BC 547 transistor. We have called this stage the audio amplifier stage. Almost any transistor can be used and we have used the most common type to indicate that it is not special. This stage is common to both the audio and VOX signals and amplifies them about 70 times before sending them in two directions, one through the mini trim pot to the VOX section and the other through a 22n-22k to the transmitter.

The load for the amplifier is a 10k mini trim pot and when the wiper is near the positive rail, the output is zero. As the wiper is brought towards the collector, more of the VOX signal is picked off and passed to another common emitter stage (we have called the audio-to-digi-

A close-up view of the VOX MkIV



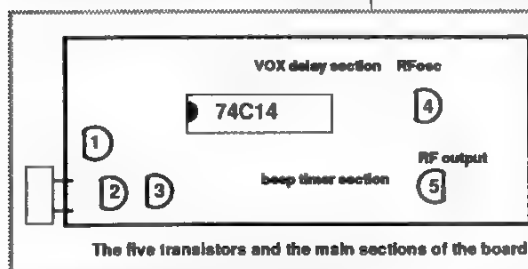
makes the stage noise-free and produces almost full-rail swing when audio is detected. The diode on the base sends the negative parts of the signal to ground (the negative rail) and leaves only the positive portions to turn on the transistor.



BLOCK DIAGRAM OF VOX MkIV

tal stage) that amplifies it further. The next stage we have called a VOX trigger stage and is designed to convert the

Since this stage is off when not required, it draws no current when the bug is in the beep mode. This makes the



The five transistors and the main sections of the board

audio signal to a digital signal to operate a Schmitt trigger inverter. A Schmitt trigger inverter requires a fairly large signal for it to change from one state to the other and the VOX stage does this by being biased OFF and only turning ON when the input signal is above .6v. This

stream of pulses.

Now for a little background on the Schmitt trigger.

A Schmitt trigger requires a level greater than 70% of rail voltage for it to see a HIGH and less than 30% of rail

voltage for it to see a LOW. If the supply is 6v, the difference between a HIGH and a

LOW is about 40% of rail voltage or a swing of 2.4v (2,400mV).

This is a fairly large waveform and to make sure this amplitude is available when we speak softly at about 3 metres from the microphone, we need plenty of gain. That's why we need three stages. The first two raise the signal to quite a few hundred millivolts and the third gives us a guaranteed 2,400mV or greater signal to operate the digital gate. The analogue-to-digital stage converts the audio signal (analogue signal) into a large signal and the "VOX trigger stage" triggers the inverter.

With three stages of amplification, even the slightest whisper at 3 metres will trigger the inverter. If you were to listen

## PARTS LIST

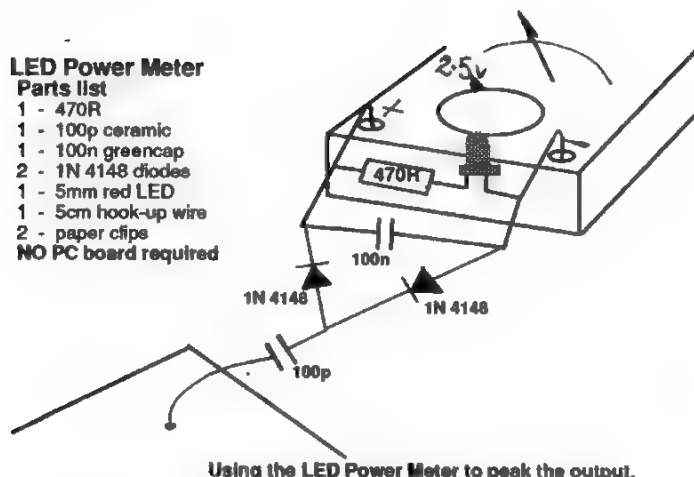
- 1 - 470R
- 4 - 10k
- 2 - 22k
- 1 - 39k
- 1 - 47k
- 1 - 10k mini trim pot
- 2 - 10p ceramics
- 3 - 47p ceramics
- 3 - 1n ceramics
- 1 - 10n ceramic
- 1 - 22n ceramics
- 1 - 100n monoblock
- 1 - 4u7 16v electrolytic
- 1 - 10u 16v electrolytic
- 1 - 100u 16v electrolytic
- 4 - 2N 2222A or BC 547 transistors
- 1 - 2N 3563 transistor
- 8 - 1N 4148 diodes
- 1 - 3v9 zener diode 400mW
- 1 - 74c14 hex Schmitt trigger IC
- 1 - 14 pin IC socket
- 1 - electret microphone insert
- 1 - 6turn .5mm wire 3mm dia coil
- 1 - 6turn .5mm wire 3mm dia coil
- 1 - 8turn .5mm wire 3mm dia coil
- 1 - spdt mini slide switch
- 1 - 15cm tinned copper wire
- 4 - AA or AAA cells (comes with AAA)
- 1 - 4-cell battery holder (extra cost)
- 1 - 175cm antenna wire
- 1 - VOX MkIV PC board
- 1 - LED Power meter kit (for peaking) available for \$1.10 extra.



### LED Power Meter

#### Parts list

- 1 - 470R
  - 1 - 100p ceramic
  - 1 - 100n greencap
  - 2 - 1N 4148 diodes
  - 1 - 5mm red LED
  - 1 - 5cm hook-up wire
  - 2 - paper clips
- NO PC board required



a loose and/or sloppy circuit such as one with long leads on the transistors or any of the other components. Keep everything close to the board and the whole circuit as "tight" as possible. The batteries should also be on very short leads and only use 4 AA or AAA cells. Don't use watch cells or a power supply from a transformer as the impedance of anything other than four cells will change the characteristics of the oscillator.

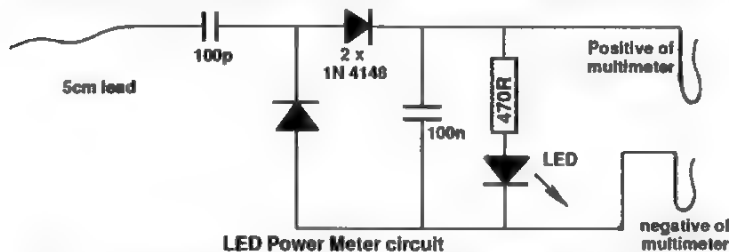
### USING THE LED POWER METER

With the oscillator working, you should tune your radio to about 88.5MHz or somewhere at the low end of the band where it is free of any radio stations and

is only coming through at one spot on the dial. If you get two or more squeals, the oscillator circuit is not tight enough and you should shorten the length of the leads of the components and close things up.

Reconnect the 47p coupling capacitor and check that the output of the oscillator does not fall appreciably. If it does, the oscillator transistor may be weak, the 47p capacitor may be the wrong value or the base of the output transistor (2N 3563) may be shorted to the emitter.

With the output stage operating you can change the peaker to the collector of the 2N 3563 and move the turns of the tank coil together or apart until the output



connect the LED Power Meter to the collector of the oscillator to act as an antenna.

A full description of this simple piece of test equipment has been given in the Ultima article (Security Devices P. 21) and the circuit has been reproduced here to assist those who have not seen this article.

Carefully push the turns of the 6 turn coil together or move them apart until a feedback whistle is heard in the radio. When the turns are pushed together the frequency decreases and when moved apart, the frequency increases. Move the radio a short distance away and tune across the band to make sure the output

reaches a maximum. In our case we got a reading of about 9v on the multimeter and when the frequency of the tank circuit is exactly the same as the oscillator, all the energy is being transmitted on one frequency and the radio will give a feedback whistle at only one spot.

If you get two peaks, the frequency of the oscillator and output do not coincide. Keep adjusting the tank coil until the two frequencies are the same.

When this is done, the project will be "peaked" and will deliver the maximum output.

When the antenna is fitted, it will load the output slightly and change the frequency a small amount. If you want to be

exact, you can re-adjust the frequency of the tank circuit by using the Field Strength Meter.

We still have two further sections to cover and if you are having trouble with the output stage or tank circuit, you should refer to the Amoeba or Ultima articles for more assistance.

### THE VOX SECTION

Next we will look at the VOX section and see how the circuit detects sounds and turns on.

Remove the shorting link on pin 2 or 4 and fit the IC into the socket. Turn the "sensitivity" pot to mid position and switch the bug ON.

Keep the radio away from the microphone to prevent feedback and you should be able to hear all the sounds in the room. If you keep very quiet the bug will turn off after about 8 seconds. If it doesn't, the 10u electrolytic is not being discharged by the 1M resistor and the fault could be a leakage path at the negative end of the electro keeping it charged. Or it could be the 10u and 1M not making contact with the positive rail. You will have to look around the negative lead of the electro with a high impedance multimeter to see why it is not going HIGH. Unfortunately you cannot put a low impedance probe (less than 10M) here as it will prevent the electrolytic discharging sufficiently for the gate to change state.

The only way to see the capacitor discharge is place the positive probe of a high impedance multimeter on the positive rail and monitor the negative of the electro. It will discharge in less than 8 seconds due to the added load you have placed on it (the meter) and if it remains charged, you have leakage coming through from the 10k, or the diode from the beep circuit.

Remove each part in turn until the leakage is located.

When the delay "times-out," the bug shuts down to its listening mode in which the oscillator and output are turned off and the only stages that are operating are the microphone, first audio stage, analogue-to-digital stage and the timer for the beeper. The current consumption falls from about 12mA to .8mA and this extends the life of the battery considerably.

The next section is the beeper stage.

### BEEPER STAGE

As soon as the bug is in the listening mode, the timer between pins 3 and 4 comes into operation and rapidly charges the 4u7 via the diode and 10k resistor. During this time the tone oscillator (between pin 5 and 6) comes into operation and produces a square wave of about 300Hz. This tone is fed into the base of the oscillator stage via a 1n capacitor and 10k resistor.

At the same time the oscillator and output stages are turned on via the diode on pin 4.

After a short period of time pin 3 sees a HIGH via the 4u7 electrolytic and the inverter changes state. This shuts off the tone and the bug reverts to the "listening" mode.

When the tone is being produced, the VOX section is prevented from triggering by the diode connected between pins 4 and 13. A few milli-seconds after the tone has ended, the bug will be ready to trigger if it detects audio.

### RF OSCILLATOR AND OUTPUT STAGES

The RF oscillator stage is the same as our original FM BUG as it has proven to be very reliable.

The only changes have been to tap off a small amount of RF from the emitter with a 47p capacitor (this has been done with hardly any effect on reducing the amplitude of the oscillator) and the zener reference.

We have found that we can draw off more energy at the emitter than at the collector and this means we can deliver more energy to the output stage. This is one of the reasons for the increased output of this design.

The operation of the oscillator has already been covered in our previous articles and the same theory applies.

The output stage has also been covered in our previous articles, including the operation of the RFC (Radio Frequency Choke) between the power rail and the tank circuit. This improves the output considerably by allowing the tank circuit to produce a larger waveform.

All these improvements add up to a very efficient design and we can boast that ours is at least 3 times more efficient than anything else on the market. Other designs require 25-35mA or more to achieve the same range.

### IF IT DOESN'T WORK

Most of the hints and guidance to testing this project have already been covered in this and previous articles.

I am surprised that so many readers ring up and ask how to solve a particular fault when we have spent so much time detailing the art of servicing.

I keep repeating myself but the fact is an electronics hobbyist is not someone who can only build a kit but someone who can also repair it!

Anyone can build a piece of equipment. After all, most of our electronic products are put together overseas by people who have

never seen a circuit diagram in their life.

Even simple repairs can be attempted without a circuit but when a major fault occurs it is necessary to approach the job in a professional way.

The first thing you need is a circuit diagram and if the project has been working, you can assume the component values are correct and the fault is a failure in one or more of the parts.

But when something doesn't work from the start, you don't know if it is faulty workmanship, faulty components or faulty design!

That's why you have to approach the repair logically as you cannot assume anything. All component values have to be checked, all voltages have to be measured and all soldering has to be inspected.

It's almost impossible to inspect your own work and the best idea is to ask someone else to check it for you.

When projects are sent in to us for servicing, we find the fault relatively quickly as we know what to look for and where to look. Bridges and shorts that appear to be ok are tested for continuity and parts that appear to be soldered are resoldered to make sure the joint is perfect.

This solves most of the troubles as many of the constructors don't realize the importance of perfect soldering and just panic when the project doesn't work first go.

For most of the troubleshooting, refer to the section on "Testing the VOX bug" as it describes how to test the bug as well as find most of the faults.

You must start at the output and work your way towards the microphone. This allows you to use

a radio as a piece of test equipment to determine the frequency of the oscillator, the signal strength, as well as the quality of the audio and the sensitivity of the microphone.

By using the LED power meter, Field Strength Meter, a standard Multimeter and a normal FM radio, you will be able to find and fix almost any fault in the bug.

The only thing you will not be able to do is increase the output as this will cause "splash-over" and the output will appear all over the band and create major interference. So don't increase the supply voltage or change the bias on the output transistor.

### SUMMARY

This bug is the top of the range at the moment, both in performance and efficiency.

It is the forerunner to a range of surveillance devices that will enable you to keep an eye on your property and possessions. You will be able to monitor your car, boat, tools and equipment from a distance.

As you can expect, our next design will have more features and as soon as we have time to complete it and give it a field test, it will be in our next security book, so watch out for it.



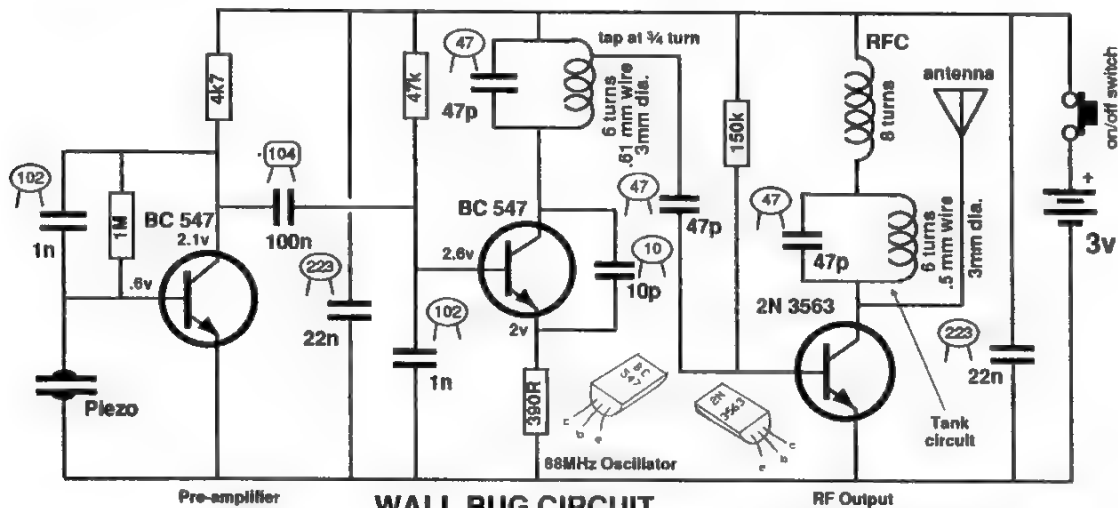
The completed VOX IV(below) compared to our next model VOX V - our surface mount version available



# THE WALL BUG

Our 400 metre WALL BUG

**Parts & PC Board**  
The LED Power to peak the outp



**WALL BUG CIRCUIT**

One day, many many months ago, an investigator rang to say he had a bug that would 'hear' through 10cm of concrete, and wanted another one. He asked if we could design something similar.

We suggested he bring it around so we could see what we were up against. It seemed amazing that you could hear through solid material and we wanted to see how it worked.

With a price tag of over \$250, it must be pretty good! But when it arrived, it was a disappointment. It was simply a 5-transistor Amplifier driving an earphone. The input was a piezo diaphragm with a probe that touched the wall and when we tried it, the amplification was quite good, but at \$250, it was grossly overpriced.

The headphone was the limitation. You had to stand at the wall, keeping the unit attached and straining your hearing at the same time.

For the price, you would expect something more for your money. The concept was fairly primitive and we decided to design something considerably better. We started with the Amoeba circuit and after a lot of experimenting we came up with a transmitting wall bug that was more sensitive than the sample we were given.

Being a transmitter, it gave you the freedom of being able to listen in comfort from a distance and you didn't have to stand around with your ear glued to a

wall! The secret of the design is the use of a piezo diaphragm. The same type as found in piezo alarms. But we use it in reverse. Instead of emitting a sound, these diaphragms are also capable of picking up a sound and converting the vibrations into electrical impulses.

But these electrical signals are very small and you need a powerful amplifier to bring them up to the level for injecting into a transmitter stage. We found the sensitivity of these units varies enormously from one type to another and the size of the diaphragm also determines the output.

To get a good result you have to use a sensitive unit. Let me point out the kits use a fairly sensitive item but the made-up versions use a device that is about 4 times more sensitive, so don't expect the kit to come up the quality of the built-up versions. Two "cats whiskers" are soldered to the centre of the diaphragm in the built-up version whereas the one supplied in the kit is a metal cased version that needs to be pushed onto the glass or other solid medium so that the vibrations will pass to the diaphragm.

The diaphragm is attached with Blu Tack and the whole window becomes a microphone. You can pick up sounds nearly as good as an electret microphone and the only trouble is you can hear sounds on the outside of the building at the same level as those on the inside. This means the sounds of

## PARTS LIST

- 1 - 390R (orange-white-brown)
- 1 - 4k7 (yellow-purple-red)
- 1 - 47k (yellow-purple-orange)
- 1 - 150k (brown-green-yellow)
- 1 - 1M (brown-black-green)
- 1 - 10p ceramic
- 3 - 47p ceramic
- 2 - 1n ceramics (102)
- 2 - 22n ceramics (223)
- 1 - 100n monoblock (monolithic)(104)
- 2 - BC 547 transistors
- 1 - 2N 3563 transistor
- 1 - 8 turn .61mm tinned copper wire 3mm dia coil
- 1 - 6 turn .5mm enamelled wire 3mm dia coil
- 1 - 8 turn .5mm enamelled wire 3mm dia coil
- 1 - piezo diaphragm
- 1 - mini slide switch
- 2 - 30cm hook-up wire - if needed for piezo
- 2 - AAA cells
- 1 - 170cm antenna wire
- 1 - WALL BUG PC BOARD

birds, cars and even wind comes through quite clearly.

It makes the old adage "Speak softly, the walls may be listening." a reality. In fact everything in the room is vibrating and it makes you wonder how safe it is

to hold any form of discussion in an enclosed area.

As with all our devices, they are to be used solely for your own entertainment and to learn the principles of sound detection through homogeneous mediums. You can experiment with our design and try to improve its performance by modifying the pickup and altering the circuit. Let us know how you go.

The most common name for this type of bug is 'Concrete Bug' however it is most often used on a window. In fact we should call it a 'Glass Bug' but somehow it came to be named 'Wall Bug.' But glass is not the only medium. It can be attached to the topside of a ceiling, providing a good 'sounding board' is created.

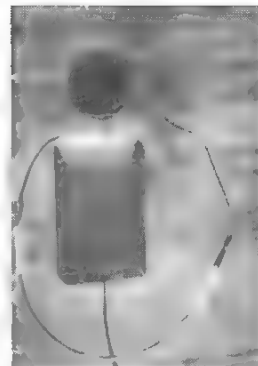
This can be done by mounting the pickup on a piece of glass or tile and laying it on top of the ceiling. It is important to make good contact between the surfaces so that vibrations will pass from one medium to the other. As far as wall bugs go, this is one of the best and will transmit about 200 metres.

It is interesting to listen to room sounds via a solid medium as you can detect the frequency limitations of various substances such as plaster, glass, tile, wood as well as the distinctly metal sound of the piezo. Also, the reverse use of the piezo

element will be new to many readers. If you have a CRO, you can connect the element to the input leads and place it on the workbench. Keep it away from the mains so that it doesn't pick up the 50Hz hum.

With the CRO set to low mV, you can whistle at a fixed distance from the unit and compare the amplitude of different types.

When the piezo is connected to the project, the voltage generated by the diaphragm is amplified by the pre-amp and passed to the RF oscillator to be converted to an FM signal for picking up by an FM radio. Further discussion on the circuit can be found in the Amoeba article.

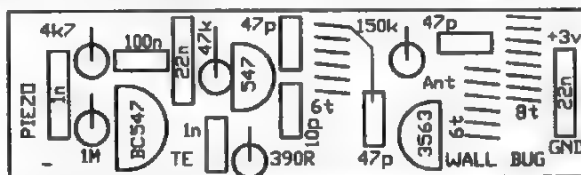


Completed wall bug mounted on glass with Blu Tac

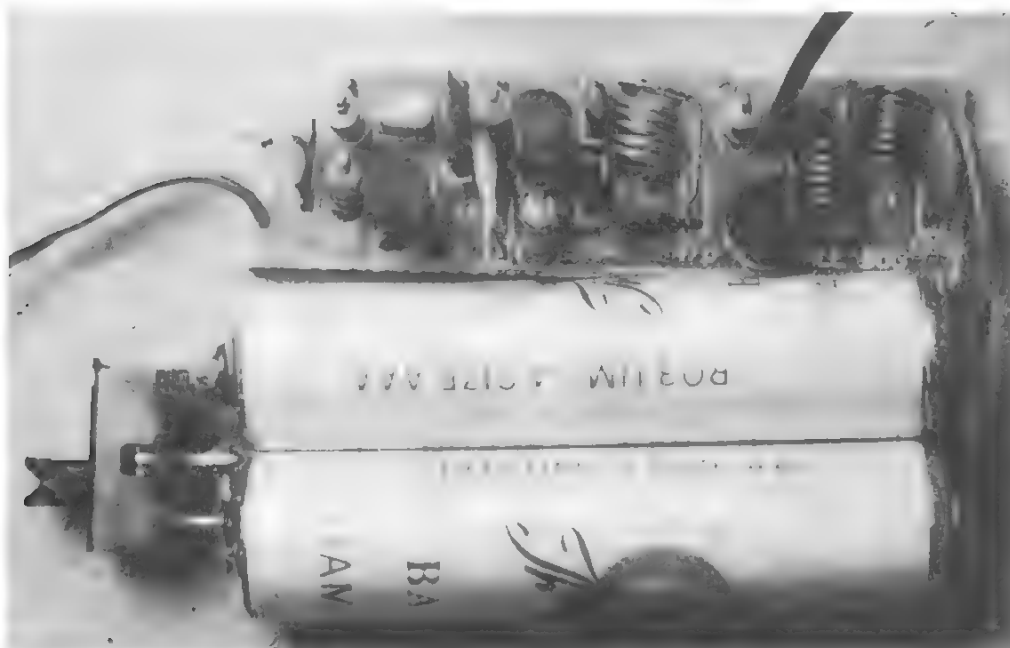
the mic load resistor and 22n coupling capacitor. The load resistor for the pre-amp has been reduced to 4k7 in the wall

### CONSTRUCTION

The circuit is very similar to the Amoeba and the only difference is the omission of the 100R, the electret mic,



Enlarged view of overlay showing detail of component layout.





bug to give the first stage a higher gain and a 1n capacitor has been placed across the piezo to prevent instability.

If you have already made the Amoeba, you will have no trouble with this project. Fit all the components to the board including the leads to the piezo. It does not matter which way around the leads from the piezo are connected to the board as the signal is what we call "AC" and it doesn't have a polarity.

Solder the batteries as shown in the photo with the slide switch connected to the opposite end of the cells and the project is ready for adjusting and peaking to a frequency away from any other radio stations.

Carry out the necessary adjustments on the oscillator and tank coil as per the Amoeba notes and fit the antenna.

Slide the circuit into a Tic Tac box and switch the unit on. You should be able to get feedback from 3 metres or more and be able to hear sounds in the room, even when the diaphragm is not touching anything.

The output from the piezo will be much better when the case is touching a solid sounding board such as glass or tile and you can do this by attaching two pieces of Blu Tac to the piezo case and pressing it firmly against a window etc.

#### FAULT FINDING

If the circuit does not produce a whistle, something in the front end will be faulty. It could be the piezo, or the pre-amplifier stage. The best way to locate the fault is with a CRO. You should get a 10mV waveform across the leads of the piezo when whistling at 30cm. The transistor in the pre-amp section will have a gain

of about 70 so the output should be about 2100mV into the oscillator stage.

If you don't have a CRO, the only other way to check the front end is with a small audio amplifier. This can be built up from a circuit similar to the dish bug and taken to a set of headphones.

Check the voltage on the collector of the first transistor. It should be higher than 0.9v, otherwise the stage will be saturated.

The three faults we found with models coming in for repair were shorts between base and emitter, piezo connected to the wrong points on the board and wrong

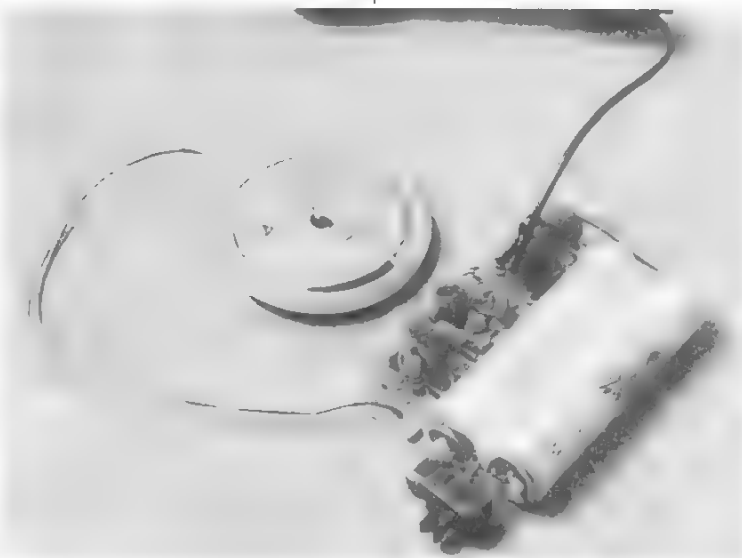


The track-work for the WALL BUG

value of load resistor for the first stage.

The only other problem we had with the front end is instability due to the 1n not being connected.

The rest of the circuit is covered in the Amoeba article and the Wall Bug should be ready for many hours of impressive listening.



## DETUNING A RADIO

In some areas, especially capital cities, the FM band is filling up very fast and it's hard to get a clear channel near the low frequency end.

One solution is to move the frequency of the bug to below 88MHz. This is called DETUNING the bug and has the advantage of providing a link that will not interfere with anyone else. It gives you a private link and you can be sure you will not be picked up by the next door neighbour.

Sometimes the 84-88MHz band has been given to couriers and other two-way radio operators and it is necessary to check before-hand by detuning a radio and listening for any sounds of life.

The detuning of an FM radio is a relatively simple job. Either the tuning gang can have an additional 1p - 3p3 fitted across it or the turns of the oscillator coil can be moved together very slightly. On some radios you can move the trimmers on the back of the tuning gang and the

stations will shift along the dial.

Any of these procedures will cause the FM stations to move up the band slightly so that a vacant space will be generated at the low end of the dial.

By adjusting the bug so that it transmits on this part of the band, you can create your own private link. Check to see that it is off the normal band, and it's done.

The coil we mentioned earlier is easy to find. It's generally an air cored coil and when you go near it with a screwdriver, the stations move along the dial. This coil is very sensitive and only has to be adjusted a very small amount to create the shift. When adjusting the bug, you may have to add one or more turns to the oscillator coil and/or the tank circuit. This will depend on the tolerance of the components and the closeness of the turns of the coil before starting the job.

When going from 88MHz to 84MHz, the turns must be moved together (without touching, if they are tinned copper wire) and it may be necessary to add an extra turn.

For those who want to go to the other end of the band, there's one word of warning. As you go higher in frequency, the gain of the transistor reduces and this means the range will be reduced. At present we are working at the extreme limit of the capability of a BC 547 and if you want to go to 107 - 110 MHz, I suggest you use a better transistor, both for the oscillator and output. Something like a 2N 3563.

The coils in the transmitter may have to be changed and possibly the best idea is to change the 47p for 39p or 33p, while you are at it.

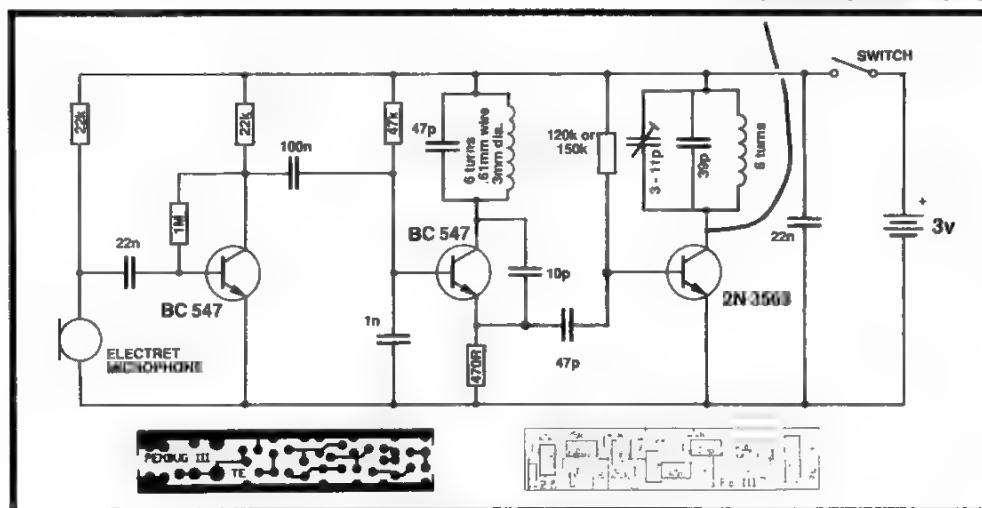
I have not tried the bugs at this frequency but I see no reason why they would not work. If you tune a radio so that it will go up to 120MHz, you will be able to pick up professional bugs as many crystal locked bugs operate at this frequency. Instead of detuning a radio, you can retune it by opening up the turns of the oscillator coil and this will bring the stations down the dial so that the 120MHz region will be receivable.

# PEN BUG MkIII

A bug that fits inside a marker pen.

Parts & I  
PC board

The Field Strength Meter  
is required to peak this project.



PEN BUG MkIII CIRCUIT

Our first Pen Bug circuit appeared in More FM Bugs and the MkII modification was presented in Security Devices. The only difference between these was the antenna arrangement. In the MkI version the antenna was wound onto a spiral and fitted into the barrel of the pen. In the Mk II version a tank circuit was added and the coil of the tank circuit used as an active antenna.

It out-performed the earlier model and now we have a further improvement of a longitudinally wound antenna and coupling between the two stages via the emitter of the oscillator.

From the outset let me say that it is very difficult to get a good range from a bug fitted inside a pen.

As you can imagine, it is practically impossible to produce an antenna with any effectiveness from inside a pen barrel and this limits the range of the bug. We got about 10 - 15 metres under good conditions and we think this is a fair achievement.

To get the greatest range it is important to peak the tank circuit very carefully so that it delivers the greatest signal into the antenna. To do this you will need the Field Strength Meter as described on P13 of Security Devices. You simply adjust the air trimmer to get the maximum output - it's a very simple procedure.

All the versions of the Pen Bug are the smallest bugs in our range, using commonly available components and here is our version III.

## CONSTRUCTION

Before starting assembly, it is important to have everything ready with the parts laid out on your workbench for easy identification.

Start at one end of the board, the microphone end, but leave the microphone to last.

Each part is fitted as you come to it and everything is easy until you come to the oscillator coil. This is mounted upright on the board and you must bend the ends of the coil so that they fit down the holes in the board. Don't squash the turns together as they may have to be stretched apart during setting of the frequency. Make sure the enamel is scraped off the leads before fitting by using a sharp blade or file or sandpaper. Continue with the rest of the parts including the 3-11p air trimmer and tank coil.

The board is now ready for the microphone, switch and batteries.

You can solder directly to the button cells if you firstly scrape the top and bottom with a blade or file. Make sure the soldering is carried out very quickly otherwise the seals on the cells will be

## PARTS LIST

- 1 - 470R 1/4 watt
- 2 - 22k
- 1 - 47k
- 1 - 150k
- 1 - 1M
- 1 - 10p ceramic
- 1 - 39p " "
- 2 - 47p " "
- 1 - 1n " "
- 2 - 22n " "
- 1 - 100n monoblock
- 1 - 3-11p air trimmer
- 2 - BC 547 transistors
- 1 - 2N 3563 RF transistor
- 1 - electret mic insert
- 2 - 6 turn enamel wire coil 3mm dia
- 2 - button cells
- 1 - mini slide switch SPDT
- 1 - 1.5m enamel wire for antenna
- 1 - PEN III PC BOARD

damaged and the contents will ooze out. These chemicals are very corrosive, so be careful.

The microphone is connected to the board with the two short wires supplied on it, so that the lead going to the case goes to the negative rail. The negative rail is the copper strip that runs the length of the bottom of the board. The microphone must be soldered very quickly otherwise the FET inside the case will be damaged and it will lose

sensitivity and produce a lot of background noise.

### WINDING THE ANTENNA

The antenna is wound longitudinally on a paper former. To determine the size of this former, take a sheet of stiff paper and cut it to about 7cm wide and wind it loosely 3 times around the project. Open it up slightly larger so that when the wire is added, the antenna will fit over the works.

Wind the wire through the middle and around the outside until the 1.5m is used up. Solder one end to the antenna point on the board.

It's best to have the antenna as far away from the circuit as possible, but if space is limited, it can be slipped over the board.

### THE CASE

The only thing we haven't provided in the kit is the case.

This has been left up to you as there are so many different types of pens and markers that will hold the project. It is preferable to use an old, dried out marker as this will save you a couple of dollars and you don't have to handle any messy ink.

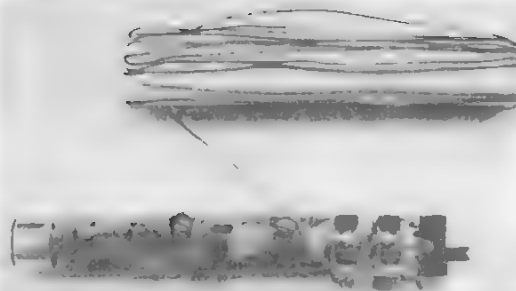
If you want the pen or marker to write normally so that no-one will suspect the contents, you will have to provide a section up the front to hold the pad of ink and this will have to be sectioned off from the rest of the barrel to prevent the ink drying out.

The main aim is to get a case that will fit the board, batteries and switch. After this you can see how much room you have for the ink.

Next you will have to work out the switch arrangement and it can be either a slide switch mounted inside, a pressure switch kept apart with a pin or a reed switch kept open with a magnet on the outside of the case.

When the pin is pulled out or the magnet removed, the switch closes and the bug is activated.

The Commercial bug (as explained the MkII article) did not have a switch. Two button cells were fitted into the barrel and the cap screwed on. The bug was then active and would operate for about 8 hours. The idea is to arm the bug beforehand and leave it at a meeting etc. Later you can go back and pick it up.



A clear view the antenna wound longitudinally on a former.

The bug we saw was actually a ball-point pen and the ink was contained in a refill near the tip. By the time we got it, the ink had run out and the only telltale difference was the larger-than-normal barrel and extra weight. Anyone with a fair degree of intelligence would become suspicious at the extra size and wonder why the pen is so cumbersome.

You could not see the hole at the end for the microphone and no external antenna was used. To get our bug to the same size as this would require surface mount components, two very small watch batteries and a lot of extra skill in construction, so be satisfied with something just slightly larger, but much cheaper.

### PEAKING

The range of the Pen bug depends almost entirely on peaking or TUNING the output. This is done by placing the Field Strength Meter near the antenna and adjusting the air trimmer until the Meter produces a maximum reading.

It is essential to be able to measure the output without physically touching any part of the circuit and this is why we use the Field Strength Meter.

You must turn the trimmer with a plastic screwdriver as any type of metal implement will change the characteristics of the circuit and give a false reading. When you see the needle fall or "dip" you have peaked the output to a maximum.

The tank circuit is now drawing the maximum energy from the battery and converting it to electro-magnetic radiation.

Place the board inside a marker pen and test the bug for both range and

clarity.

If you are satisfied with the results, fit some small pieces of foam to prevent the board moving around and fit the pen tip. Now you are ready to try it out. Ask someone to use your "Pen" and see if they notice anything different. Don't let them know or they'll want one too!

### IF IT DOESN'T WORK

Most of the problems will occur in the tank circuit section as it is important to peak this stage very accurately to get the maximum output.

The first thing to do is test the oscillator section by connecting a Peaker to the collector of the oscillator transistor. If no output is detected, remove the 47p coupling capacitor and try again.

If still no output, go over the layout of the components, making sure none of the tracks short together. Since the board is very compact it is very easy to create a solder bridge or fit a component into the wrong holes.

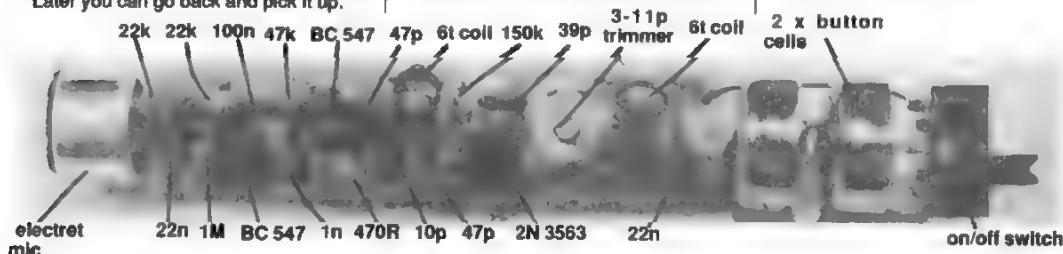
Once you are sure the oscillator section is working, connect the 47p coupling capacitor and place your Field Meter near the antenna.

If no reading is detected, the output stage is faulty. Try replacing the RF transistor and check the layout.

Once you can detect a small output from the antenna, adjust the trimmer until the output is a maximum.

Don't forget the plastic screwdriver (such as a knitting needle). Once it's a maximum, don't touch anything as you fit it into a case or you will upset the output.

It's now ready. Have lots of fun.

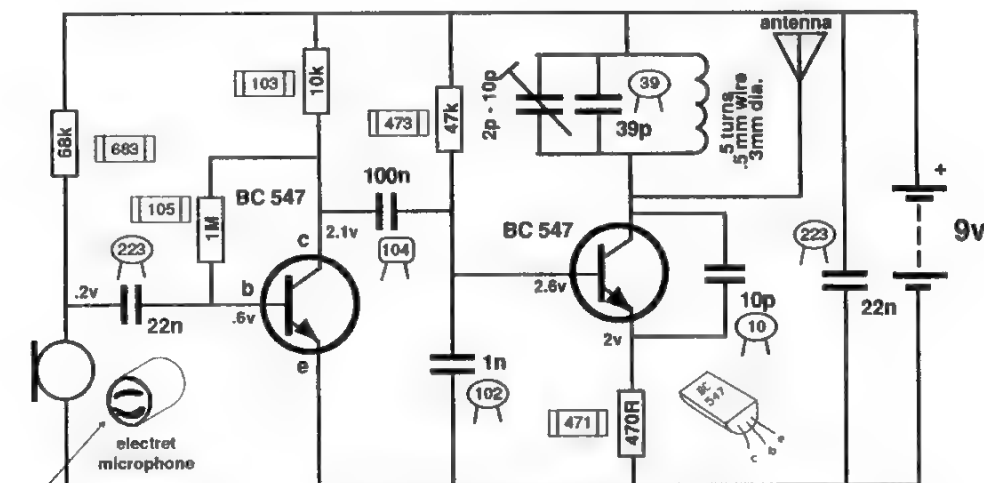


# VOYAGER MkII

## Our 800metre Voyager MkII has a number of improvements

### PC Board (on

**The LED Power Module**  
testing the output.  
it is not essential.



### Case of electret mic goes to negative rail

## VOYAGER - MkII CIRCUIT

This is the improved version of our popular VOYAGER FM transmitter. The circuit has been improved, the layout has been changed and the board has been produced on CAD.

This has given it a better layout than the old taped-artwork board and everything is marked on the topside to help you with assembly.

The other difference is the board sits upright on the top of a 9v battery with the battery snap fitted to the side of the board via short lengths of tinned copper wire as shown in the photos, whereas it laid flat on the battery in the earlier model.

Standing the board upright makes the battery snap very strong and it is easier to connect and remove the board from the battery without damaging the tracks.

The other major difference is the addition of an air trimmer so that you can adjust the frequency slightly after the project has been heatshrunk. This will allow you to move it away from any other radio stations.

When we first started to produce these transmitters the FM band had only a few radio stations and it was easy to get a free spot on the dial.

But in the past few years the band has filled up considerably and it is now almost impossible to get an empty spot where you can experiment.

That's why we have had to include the

air trimmer. After the project is complete and heatshrunk, (you need to supply your own length of heatshrink tubing) final tuning can be carried out by cutting an opening in the heatshrink for the top of the trimmer so that it can be adjusted with a small non-metallic screwdriver.

## SUMMARY OF SPECIFICATIONS

**Range: 800 metres**

**Supply: 9v**

Current consumption: 7mA

**Battery life: 50 hours for ZnC**

**100 hours for alkaline**

**Tuning range:** 80 - 110MHz (by stretching or compressing the oscillator coil)

**Fine tune by adjusting the air trimmer (2MHz adjustment)**

**Stability:** Bug to be left in situ - not to be moved or handled.

Antenna length - 170cm

I should also mention that two slight modifications have been made to the circuit. One is the change in value of the base bias transistor for the oscillator. It has been changed from 220k to 47k as we found the 220k produced a small amount of distortion or hollowness to the audio, giving the impression that the sound was coming through a pipe.

The other change is the positioning of

## PARTS LIST

- |   |   |      |               |         |
|---|---|------|---------------|---------|
| 1 | - | 470R | surface mount | (471)   |
| 1 | - | 10k  | "             | " (103) |
| 1 | - | 47k  | "             | " (473) |
| 1 | - | 68k  | "             | " (683) |
| 1 | - | 1M   | "             | " (105) |

- 1 - 10p ceramic
- 1 - 39p ceramic
- 1 - 1n ceramic
- 2 - 22n ceramics
- 1 - 100n monoblock (monolithic)
- 1 - Air trimmer 2p - 10p
- 2 - BC 547 transistors
- 1 - 5 turn coil .5mm enamel wire
- 1 - electret mic insert - high sensitivity
- 1 - 9v battery snap
- 1 - 9v battery
- 1 - 15cm tinned copper wire
- 1 - 30cm fine solder
- 1 - 170cm antenna wire

1 - VOYAGER - MkII PC BOARD

the microphone. It is now mounted on the side of the board so that the board is easier to heatshrink.

These modifications are a result of us making hundreds of Voyagers for customers and the new layout is really a dream to put together.

If you have not built any of our FM transmitters, this is one you should not miss out on.

Before I start, let me say that these transmitters are called "bugs" so that

they can be described quickly and easily in the text.

They have been designed exclusively so that you will learn the techniques of FM transmission and get the greatest range possible with the minimum of power.

Under no circumstance are you to use or try to use any of them for any improper purpose (if this is possible) and you are to follow the laws in your state, governing their use.

There is no law preventing us showing you how FM transmission works and you must respect our efforts by keeping the airwaves free from interference.

I am sure you will be building these transmitters as a learning exercise and suggest you start at the beginning by building some of the other projects first.

We have compiled the best range of FM transmitters you will ever come across in this book. Each project has been designed to add features to the basic ANT design so that you can see how the range can be increased by adding such things as a tuned output, RFC, emitter coupling, and by increasing the supply voltage.

In this project we will show how increasing the supply voltage improves the range and at the same time we introduce miniaturisation in the form of surface-mount components.

To make construction as simple as possible, we have decided to start with surface mount resistors. Some of the other components such as chip capacitors and transistors are so small that they are almost impossible to solder by hand.

Surface-mount technology is entirely different to normal through-hole placement and some of the differences are explained in this article.

The major difference is size and if you are having trouble picking up and placing 1/4 watt resistors, you will have ten times more difficulty with surface mount. SMC items are so small that it takes the keenest eyesight to read the figures on the component and the nimblest of fingers to pick and place them.

But until you buy a kit and see what the parts look like, you will have no idea if you will be able to cope.

Nevertheless surface mount has arrived and is here to stay. Within a few years most manufacturing will include surface mount components and already many designs are entirely surface mount.

Since this will possibly be your first introduction to surface mount, we have decided to introduce it slowly and use normal components for the majority of the circuit and chip resistors for the surface mount section.

Although this may not take up less space, and is sure to work out more expensive, it is the only practical way to start.

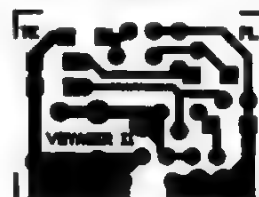
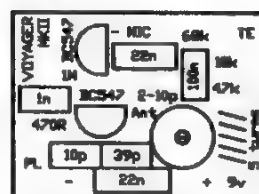
Most SMC's are extremely difficult to buy and very expensive. I don't know of any outlets that sell individual items and only a handful that sell them in lots of 10 or 100. We have to buy them on a reel of 1,000 to 5,000 pieces and this is way beyond the needs of an average hobbyist.

Some of the components for the Voyager are not available in surface-mount form (such as the coil and air trimmer) and anyway the battery is the largest component so there's little point going to extreme lengths in miniaturisation.

The electret microphone is also difficult to get in miniature form and when we tried to get one about a quarter the size of our present unit, about 4 years ago, from a hearing aid manufacturer, we were quoted an astounding \$32 each!

We subsequently imported our own and sell them for about \$3.00 each. Who do you think bought 100 of our mic's! Yes, the hearing aid manufacturer!

The main reason why we started with chip resistors is their relative ease of handling. Chip capacitors are half the size and have no identification. The



Actual size artwork showing the size of the board and the top overlay.

other factor that makes them very frustrating is their size does not correspond to the value. This is due to the way they are manufactured and the thickness of the layers of substrate.

The main difficulty with surface mount is placing them on the board and holding them in place while soldering. There are a number of aids to help you with this, such as solder pastes and solder creams, silicon and infra-red setting glues but most of these come in syringes and cost as much as \$20 for a 25gm tube. For a simple project, this additional cost is out of the question.

To keep costs down we are going to hand solder each resistor without the aid of glue and the technique we use is called RE-FLOW SOLDERING.

Basically it consists of heating up the solder on the PCB board AND THE END OF THE RESISTOR AT THE SAME TIME so that the resistor makes a perfect connection to the board. More is mentioned about this in the assembly section.

For now, all you have to do is read through the article and make sure you know how the project is going to go together, before starting.

## HOW THE CIRCUIT WORKS

The circuit consists of two stages - an audio amplifier and an RF oscillator.

The electret microphone contains a FET transistor and can be counted as a stage, if you wish. The microphone detects audio in the form of



air vibrations that enter the hole at the end of the mic and move the diaphragm. This diaphragm is a thin piece of metalised plastic such as mylar and is charged during manufacture. The relative distance of the mylar film to the outer case makes the charges move on the

pedance and does not have any loading effect on the charges. The audio amplifier (BC547) has a gain of about 70 and amplifies the signal and passes it to the base of the oscillator stage.

The oscillator is designed to operate at about 100MHz and this frequency is set by the value of inductance of the 6 turn coil and the capacitor across it. The frequency is also determined to a lesser extent by the transistor, the 10p feedback capacitor and also the biasing components such as the 470R emitter resistor and 47k base bias resistor. The supply voltage also has an effect as the oscillator can be classified as a voltage controlled oscillator.

So, there are a lot of things that set the frequency and even though the parts have a 5%, 10% or 20% tolerance, the frequency can be set very accurately by moving the turns of the coil closer or stretching them apart and then adjusting the air trimmer to the precise frequency you require. The circuit will stay at the desired frequency providing the supply voltage remains con-

The operation of the oscillator section is quite complex, so to keep things simple we will commence the discussion when the transistor gets turned on via a pulse from the 10p feedback capacitor. At the end of the discussion you will see how this pulse is generated.

First let me explain how the voltages are set on the oscillator transistor.

The 47k base resistor turns the transistor ON and its value is such that it does not turn it on fully. The feedback pulse from the 10p turns it ON fully by lowering the emitter voltage and OFF fully when it is in the opposite direction.

We normally turn a transistor on and off via the base but the same can be done by holding the base firm and changing the voltage on the emitter. In the Voyager, this is what happens. The base is held firm by the 1n capacitor and the emitter voltage is increased and decreased by the action of the 10p feedback capacitor.

For the capacitor to be able to do this, the emitter must have a DC voltage that can be increased and decreased. This DC voltage is determined by a number of factors that are quite complex and we measured our prototype and found it to be 2v. The base will be .6v higher at 2.6v. To measure the base voltage you need a very high impedance multimeter so that you don't load the circuit and get a false reading.

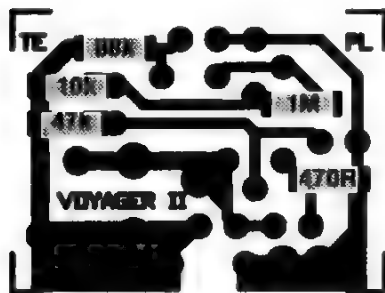
The base voltage is fixed at 2.6v by the 1n capacitor and does not rise or fall when the oscillator is operating. (It only rises and falls when the audio is injected into the base from the 100n capacitor from the audio stage.)

So, where do we start?

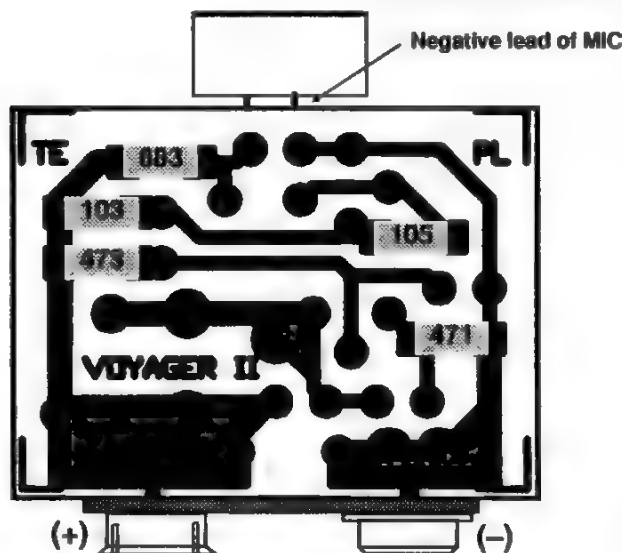
The best place to start is the tuned circuit. The capacitor and inductor are in parallel and form a tuned circuit. They find it very easy to pass energy back and forth and when a small amount of energy is delivered to them via the transistor, the waveform generated by them is sinusoidal and if we imagine the transistor is removed for a moment, we can see that the 10p capacitor detects this waveform and passes it to the emitter resistor..

If we put the transistor back we can see that a pulse that reduces the voltage on the emitter will make the voltage between the base and emitter larger. This action turns the transistor ON and delivers a burst of energy to the tuned circuit. As the waveform continues through its cycle, a point will be reached where the pulse through the feedback capacitor will be in the opposite direction and this time it will turn the transistor off.

This is how the circuit works and continues at the incredible rate of 100 million times per second.



The resistor values as compared to the circuit diagram.



Twist two pieces of tinned copper wire together and use it to solder the positive and negative terminals of the 9v battery snap to the PC board.

diaphragm (as like charges repel etc). Some of them pass down a lead that touches it and into a FET transistor. The FET amplifies the charges and gives a reading at the output lead. The reason why a FET has been used is due to the fact that it has a very high input im-

pedance and does not have any loading effect on the charges. The audio amplifier (BC547) has a gain of about 70 and amplifies the signal and passes it to the base of the oscillator stage.

The voyager is not designed to be handled and is not suitable to be worn on the body - we have other circuits for this type of application.



## RESISTOR AND CAPACITOR VALUES

With the size of resistors and capacitors getting smaller and smaller, the space for identifying the value is getting less and less.

To make things simple, a uniform numbering system has been adopted, consisting of three digits. The first two give the value of the capacitor in pF or the value of resistance in ohms and the third digit is the multiplier.

This brings both capacitors and resistors into the same code and once you can read the code, you can identify everything.

As an example, we will take a 47k resistor. See the third chip in the diagram opposite. The digits are 4 - 7 - 3. The digit "3" represents the number of zeros to put after the number "47." Thus we get 47,000 ohms.

A 470 ohm resistor is "47" and one zero, thus we get 471 on a chip. A 10k is "10" and three zeros, thus 103 is written on the chip. A 68k is written "68" and three zeros, thus 683 is written on the chip and 1M is written "10" and five zeros. Thus the chip has 105 on it. These are the five values used in the *Voyager*.

A 10 ohm resistor is "10" and NO ZEROS, so the marking is 100. I know, I don't like it either but 150 on a chip is 15 ohms and not 150 ohms. 150 ohms is "151." Don't ask me what 1 ohm is because surface mount resistors start at 10 ohms and go to about 4M7.

It's only the range from 10 ohms to 100 ohms that will cause problems. When you see markings such as 120, 180, 470 etc it is best to check the resistance with a multimeter, to make sure the resistances are 12 ohms, 18 ohms and 47 ohms.

Keeping this in mind, we go to the markings for capacitors. The basic unit for surface mount capacitors is pF (sounded 'puff') and instead of using the word kilo for thousand (as with resistors) we use nano ('n' for short). Thus 102 is 1n and 103 is 10n. Extending this further we get 104 for 100n and 105 for 1uF.

For those who have to convert from the old system, 10n is equal to .01uF and 100n is .1uF. 223 is 22n or .022uF and 1n is 1,000pF or .001uF. For surface mount capacitors, you must think in pF. This will allow you to build our next surface mount project and any others in the future.

One point to note: With surface mount capacitors, the size of the chip is no indication of capacitance. The structure of the chip can be single layer or multi-layer and this affects the size.

### WHY?

How many times have you built a project and it doesn't function as



The 5 chip resistors used in this project are: 470R, 10k, 47k, 68k and 1M.

described?

Don't blame yourself, it could be due to poor circuit design, in which the values chosen by the designer are not the most suitable. Let's look at how this comes about.

All components have a spread of parameters called TOLERANCE. This includes resistors with a tolerance of 1%, 5% or 10%, capacitors, (with a tolerance of 10%, 20% or even 50%), transistors, electret microphones, coils and even integrated circuits.

Then we have another factor called "limits." Each component in a circuit should be chosen so that its value is the most appropriate to that required. In other words, the circuit should work equally well if we select the next higher value or next lower value. If not, the circuit is very critical or the chosen value is not the most appropriate.

The amount by which a value can be increased or decreased and still allow the circuit to function, is called the LIMIT.

When a project is published in a magazine or book, there is an enormous range of builders with varying skills, drawing their supplies from many different sources.

Sometimes they use the designated values, other times they use the next value. Some components have tolerance values of  $\pm 5\%$  while others can be as much as 50% higher than the marked value. When these variations are combined, you can quite often come up with a circuit that does not work!

Take an electret microphone for example. On a 3v supply, some microphones are super-sensitive with a 47k load resistor, others may require a 4k7 to get a barely acceptable result.

By looking at the two you could not tell them apart. It's only when you put them in a circuit that the difference is detected. The microphones we buy for the *Voyager* have a very high sensitivity whereas most microphones that are available from hobby shops are medium sensitivity. Our transmitters are capable of picking up the ticking of a clock from 3 metres or the slightest whisper from 5 metres. There is no way of changing the sensitivity of an electret microphone, it's all in the charging of the mylar film inside the unit, during the time of manufacture.

There is also an enormous variation in the quality of transistors. Some manufacturer's produce very poor quality devices while the same type from other manufacturers may be superb.

This is one of the main reasons why it's best to buy a kit. Kit suppliers know which brand is best and only supply the best quality. By buying a kit, the risk of failure is minimized.

## ASSEMBLY

Before you do anything, prepare the workbench.

Lay out a couple of sheets of clean white paper and place the kit of parts on one. Don't take the resistors out of the carriers until you are ready - a resistor dropped may be a resistor lost.

Study the board and note that all the components are identified by the printing on the top of the board, called the overlay or legend. You really don't need any instructions at all, but since this may be your first attempt at surface-mount, we will give you some helpful hints.

Note how the board stands on top of a 9v battery, with the battery snap soldered to the edge of the board. The positive and negative lands on the board are large so that the connections to the snap will be strong.

The microphone fits on the top of the board with two short wires and overhangs the board. Some microphones come with wires attached and this makes them easy to fit. Other microphones may need to have wires attached and these can be obtained from the ends of capacitors.

The only 4 components that have to be fitted around the correct way are the two transistors, the microphone and battery snap. All the other parts, including the capacitors, air trimmer, coil and resistors can be soldered around either way.

Once you have studied the photos, the PC board and components, you can start.

Here is the order for assembly:

- 5 surface mount resistors.
- 6 capacitors.
- 2 transistors.
- air trimmer
- 5-turn coil
- battery snap
- microphone.
- antenna lead.

Now for the finer points:

The surface mount resistors required a fair degree of skill and you have to be good at soldering if you want to make the board look neat.

Refer to the two diagrams on the following page and note the top diagram shows where each of the resistors goes according to the values shown on the

circuit diagram. The lower diagram shows the values of the resistors according to the 3-digit resistor code.

Place the strip of resistors on the workbench and take one out of the carrier strip, keeping the code numbers on top. Turn the resistor around so that the numbers make sense (make sure you don't read the numbers around the wrong way!) and place it on the board as shown in the photo and diagram, so that it is correctly placed on the solder lands.

There are two ways of soldering the chip. One is to sit it in place and heat one end with a soldering iron while applying solder and then repeat with the other end.

The other is called RE-FLOW.

In this method, you add a little solder to each land and tin each end of the resistor while holding it in your fingers. Yes! You can actually hold the chip while soldering the opposite end. If you can't, you are taking too long.

When both the lands and the ends of the chip are tinned, it is placed in position and held with a piece of wire such as a paper clip while one end is touched with a soldering iron. This is repeated with the other end.

It is important not to put any force on the chip as you are soldering it as the ends can be easily fractured and the resistor will go open circuit. A hairline crack will be produced that you will not be able to see. The only way to check that the resistor has not been damaged is to measure it with a multimeter.

The other 4 chips are placed on the board in exactly the same way, making sure they are covering the lands and sitting flat on the board.

Double check the codes and if everything is correct you have carried out your first surface-mount construction!

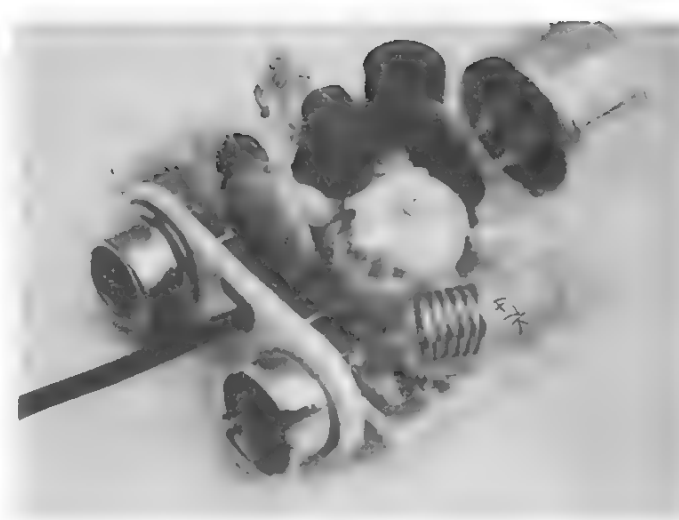
The rest of the assembly is a lot easier, it's just a matter of doing things in the correct order.

All the other components are mounted on the top of the board and when two formats are combined like this, the assembly is called HYBRID.

Refer to the layout diagram for the placement of the 6 capacitors. These are soldered in place, one at a time. Some of the leads may have to be bent slightly to allow the component to fit down the holes as it is almost impossible to get all components in either .1" or .2" spacing.

Next, the two transistors are soldered in place. Push them down as far as they will go as we want to keep the profile low. In addition, we have designed the circuit with the transistor leads as short as possible. If you place the transistors high off the board, the performance of the oscillator will be different to our prototype.

Solder the leads quickly so that you don't heat up the transistor too much.



The air trimmer is next. This must be soldered very quickly otherwise the plastic insulation between the plates will melt. Keep a finger on the trimmer to act as a heatsink and everything will be ok.

The coil is made from enamel coated wire and this coating must be scraped off with a knife or burnt off with a hot soldering iron so that the two ends are bright and shiny and TINNED before fitting to the board.

The kit comes with a pre-wound coil but if you are making it yourself, here are the details:

Wind 5 turns of 24B&S (.5mm) or 21B&S (.71mm) on a 3mm diameter shaft such as a medium Philips screw driver and space the turns as shown in the photo.

The coil determines the frequency of the oscillator and the turns will be stretched apart or squashed together after the project is complete. At this stage it does not matter about the spacing of the turns, as long as the ends fit neatly down the holes in the board.

If you have made the coil from enamelled wire, don't forget to tin the ends. This is done while the coil is on the screwdriver so that it acts as a heatsink.

Push the coil up to the board and solder it in place with the turns evenly spaced.

Now the battery snap. If you want this project to get the range we have specified, the circuit must be as tight as possible and this means the battery must be as close to the board as possible. To do this we take a battery snap out of its plastic jacket and solder it directly to the edge of the board. The "crown" terminal is soldered to the positive land on the board. Use plenty of solder at it is necessary to make a good mechanical connection.

The terminals must not be able to be rotated and if they can be turned, they should be soldered at the centre of rotation. Use very little solder inside the crown as the positive terminal of the battery must be able to fit inside it to make contact.

One of the last components to fit is the microphone as its two leads are very fine and any bending will cause them to break.

The microphone in the kit comes with two short wires attached and if you look at the solder-lands on the back you will see one goes to the case. This is the negative terminal and must be soldered down the negative hole on the board. See the Gnat article on pages 26 and 27 for a close-up of the bottom of the microphone, and circuit diagram.

Finally the antenna. This is soldered down the hole marked "ant." You have a choice of two antennas, a 15cm tinned copper wire antenna and a 170cm half-wave antenna. This has been done to allow you to experiment as the main purpose of these FM transmitters is to achieve the greatest range with the least power. We want you to try different antenna combinations to see which is the most effective.

If you only want about 30-50metre range, the 15cm antenna will be sufficient but if you want to get the maximum range, you will need the half-wave antenna.

## SETTING UP

Once all the components have been soldered in position, the project can be set up and tested for performance. The test procedure is to connect the LED Power Meter to the antenna point on the board.

The construction and use of the LED Power Meter is covered in the Amoeba article on page 28. It is designed to take the RF output and turn it into a DC voltage so that you can read it on a multimeter.

By using this piece of test equipment you can determine if the project is delivering an output, however you do not know if the frequency is on the FM band or outside it - this will be the next test. But firstly you should see if the output is between 6v and 12v, for a 9v supply. The variation in voltage will depend on the quality of the oscillator transistor, the frequency being produced and the "tightness" of the circuit.

The next step is to see if the output is on the FM band and to do this you can leave the LED Power Meter connected to the output as its short lead will act as an antenna.

Bring an FM radio near the project and turn the volume up full so that when you tune across the band, you will hear a squeal when the frequency is detected.

By moving the Voyager away you will be able to pick up the sounds it detects. Make sure the frequency of transmission is well away from any radio stations as the signal from a station will swamp the Voyager when you are testing it for range. You can do this by adjusting the air trimmer. You can see the vanes moving in and out of mesh with the stators and the meshing should be midway at the start so that you can raise or lower the frequency by turning the trimmer.

As the vanes move out of mesh, the capacitance of the trimmer decreases and the frequency of the bug increases. When adjusting the capacitor you must use a non-metallic instrument. The best is a plastic knitting needle filed to make it into a flat screwdriver.

If you do not get a squeal from the radio you can assume the frequency is lower than the band (as we have designed the output to be very close to the bottom of the band) and it may be just a little too low.

In this case you will have to raise the frequency by expanding the turns of the coil. This will bring the output onto the FM band and you can shift it slightly up or down with the air trimmer to get it away from other stations.

You can now solder the short antenna onto the board if you require a range of about 30-50 metres or use the half-wave antenna if you want 800 metres.

To get the maximum range, the antenna should be stretched out straight and placed either horizontally or vertically. The receiving antenna must be in the same plane to get the maximum range and both antennas should be as high as possible.

The signal is generally not affected by brick walls, glass or plaster but it will not pass through metal of any kind such as the foil insulation that is currently required in the walls of new buildings.

The signal will also find it difficult to get out of a car and you must place the antenna near a window but not close to the metal frame-work as this will almost totally absorb the signal. The range from a car will be limited to about 100 metres so don't expect any more.

In the open, you should be able to get a lot further than 800 metres as our test was made from our assembly room and over a slight hill so that we can offer a genuine range as might be expected in a normal situation.

### IF IT DOESN'T WORK

If you cannot detect an output on the LED Power Meter, you can safely assume the oscillator stage is not working.

Measure the current for the project. It should be about 7mA. If it is only about 3mA, the oscillator transistor may be damaged or not being turned on. The only voltage you can measure with an ordinary multimeter is the emitter (2v), as the base requires a very high impedance meter to get an accurate reading. If the emitter is zero, the transistor is not being turned on and you should check the 47k base-bias resistor. If it is about 3v, the 10p feedback capacitor may be open. If it is 9v, the transistor may be shorted or the 470R resistor may be open circuit.

But the most likely cause will be a soldering fault, such as a bridge between two tracks, poorly soldered joints, or two components that have been swapped - such as the 47k and 470R.

The best thing to do is give the project to someone else to check as it is very difficult to check your own work.

If you have used your own parts to build the project, the fault could be in the markings on the components (or incorrect reading of the values) or the wrong size coil. The only solution is to buy a kit and put it together - you can then compare one project with the other.

If you are picking up a blank spot on the dial but no audio, the fault will lie in the first stage or the microphone.

Check the voltage on the collector of the audio transistor. It should be about 2v, however if it is above 6v or less than 1v, the transistor will not be biased correctly and the 1M base-bias resistor may be at fault.

The electret microphone needs only about 50mV across it to work correctly and the only real way to check it and the audio stage is to use a CRO or audio amplifier (our prototype had 200mV across the microphone). By whistling into the microphone at a distance of

about 30cm you will get an output of about 10mV - 30mV. The audio transistor will provide a gain of about 70 and produce an output of about 700mV - 2,100mV.

If the microphone does not produce at least 10mV, it may be around the wrong way, damaged, or have very low sensitivity. Reducing the 68k load resistor may help if the microphone is a low sensitivity type.

### FITTING THE BATTERY

The Voyager is designed to fit on top of a 9v battery and doesn't need any case or potting. The safest thing is not to enclose it at all.

Fully-assembled devices are available from Talking Electronics for those who are not good at soldering or want a built-up unit. They are covered with heat-shrink so they can be safely handled and placed in position to monitor the surroundings. You can heatshrink your model by buying a short length of tubing and placing it over the board and shrinking with a candle or gas torch. Crimp the ends with a pair of pointed-nose pliers so that they stick together and make a good seal. Cut around the two battery terminals and make a smaller hole for the air trimmer so that the frequency can be adjusted, and the project is ready for use.

## SURFACE MOUNT PACKS CHIP RESISTORS

1/10TH WATT  
2 off each value 10 ohms to 1M  
(60 resistors)

**\$12.00 plus \$1.50 post**

## CHIP CAPACITORS

2 off: 10p to 100n, 10u, 47u  
(60 capacitors)

**\$18.00 plus \$1.50 post**

Send to:  
**TALKING ELECTRONICS**  
35 Rosewarne Ave,  
Cheltenham, Vic. 3192

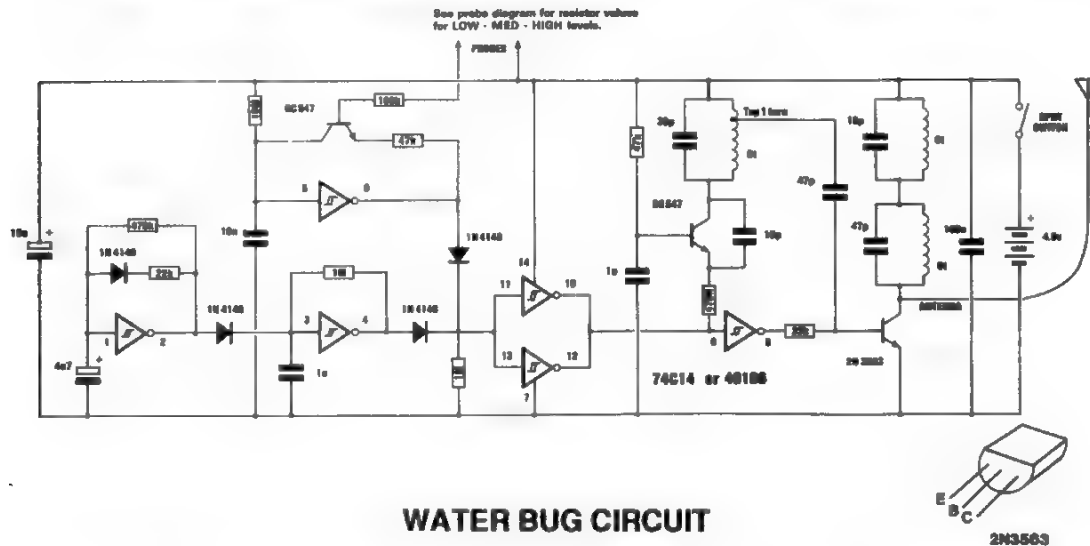
There's nothing much more to talk about except to say that if you liked the challenge of working with surface-mount components, we have produced a more advanced FM transmitter, called the VOX V, also included in this issue. It is available for \$32.50 plus post and offers a real challenge in surface-mount construction. Please refer to the price list in the centre pages of this issue as you will need the LED power meter and Field Strength Meter to assist you in getting the best performance out of the bug.

# WATER BUG

Detects water and transmits up to 1km

Parts & PC board  
PC board (only):

The LED Power Meter is required  
to peak this project: \$1.10



This project first appeared in "Bugging and Its Prevention," Page 21. It has been reduced from 5 pages to 2 to fit into this issue.

Very few of "Bugging and Its Prevention" are available and if you are lucky enough to get your hands on a copy, you can read the full article as it covers the construction in more detail.

The WATER BUG can be used to monitor remote situations such as dams, basements, fields etc to determine the presence or absence of water. A set of probes connects to the input of the circuit to enable to you determine the level of water and as it rises, the pitch of the tone increases. In the kit we have provided for three water levels: LOW, MED and HIGH.

The advantage of this circuit is it consumes very little power when sitting around as current is only drawn when the bug is transmitting. This means even small cells such as AA or AAA will last 3 to 6 months or more.

## CONSTRUCTION

The project requires a fair degree of skill in construction and you should have built a couple of our simpler bugs beforehand to make sure you are good at recognising the components and can solder neatly.

Use the overlay on the board and also the photos and diagrams in this article to help with assembly.

All the parts fit onto the board. Some resistors stand up while others lie down, depending on the space available. The diodes, transistors and IC must be placed around the correct way, otherwise they may be damaged when the supply is connected.

The 47p between oscillator and output is soldered directly to the first turn of the tinned copper wire coil. We say the first turn but it is really only about 3/4 of a turn from where the wire emerges through the hole in the board. Make sure it is the turn near the edge of the board as tapping the other end of the coil will prevent the circuit from working.

The notch or dimple at the end of the IC indicates pin 1 and this fits over the dot on the PC board. The IC socket has one corner cut off and this identifies pin 1 so place this corner over pin 1.

The overlay on the board shows how the transistors are placed and they are pushed down close to the board so that they are not higher than any of the other components.

The black band (or may be another colour) on the diodes indicates the cathode and this goes down the hole indicated with a line as shown in the diagram on the next page.

## PARTS LIST

- 1 - 470R (yellow-purple-brown-gold)
- 1 - 22k (red-red-orange-gold)
- 1 - 33k (orange-orange-gold)
- 2 - 47k (yellow-purple-orange-gold)
- 1 - 100k (HIGH tone) brown-black-yellow
- 1 - 470k (MED tone) yellow-purple-yellow
- 1 - 470k (yellow-purple-yellow-gold)
- 1 - 1M (LOW tone) brown-black-green
- 2 - 1M (brown-black-green-gold)
- 1 - 10M (brown-black-blue-gold)
- 1 - 10p ceramic
- 1 - 18p ceramic
- 1 - 36p ceramic
- 2 - 47p ceramics
- 2 - 1n ceramics "102"
- 1 - 10n ceramic "103"
- 1 - 100n monoblock "104"
- 1 - 4u7 PC mount electrolytic
- 1 - 10u PC mount electrolytic
- 2 - BC 547 transistors
- 1 - 2N 3563 RF transistor
- 4 - 1N 4148 diodes
- 1 - 74c14 (40106) Hex Schmitt IC
- 1 - 6 turn tinned copper wire coil
- 1 - 6 turn enamelled wire coil
- 1 - 9 turn enamelled wire coil
- 1 - 14 pin IC socket
- 3 - AAA cells
- 1 - SPDT slide switch
- 1 - 175cm twin hook-up wire
- 1 - 50cm twin hook-up wire
- 1 - 20cm tinned copper wire

## 1 - WATER BUG PC BOARD

When all the parts have been fitted and the probes connected, we do three things for the final stage of alignment:

1: Check the current consumption of the circuit. 2: Set the frequency to between 88MHz - 90MHz and 3: Peak the output.

### CURRENT CONSUMPTION

Firstly we measure the current consumption. It should be almost zero (about 20 microamps) when the circuit is timing and not more than 20mA when it is producing a tone.

Since the tone burst is very short it will be difficult to get a reading on a multimeter and all you will see is the needle flicking very briefly.

To find out how much current the circuit consumes, you must jam it ON by connecting pins 11 and 13 of the IC to the positive rail.

The tone will not be produced during this operation but the oscillator will produce a constant carrier and the output stage will provide a signal that can be picked up by a radio as a "quiet spot."

If the current is between 10-20mA, everything is working ok. A current higher or less than this indicates a fault and the section on "IF IT DOESN'T WORK," in VOX MkIII (later in this issue), will help locate the fault.

### SETTING THE FREQUENCY

The next job is to set the frequency. Most of our bugs are designed to operate at about 88 - 90MHz and you should search for a free spot on the dial where there are no radio stations.

Remove the antenna lead and while pins 11 and 13 are connected to positive, connect the input of the Peaker to the collector of the oscillator transistor and move the turns of the oscillator coil so that the radio picks up the "quiet spot." By pushing the turns of the oscillator coil together, the "spot" will move down the dial and when separated, the spot will move up.

At the moment, the Peaker is acting as a short antenna and we are not concerned with the reading on the meter. As a matter of interest, it should be about .5v to 1v.

Now remove the peaker from the oscillator stage and place it on the collector of the output transistor. Here the reading will be higher and we are still using the Peaker as a short antenna.

Without touching the radio, adjust the turns of the 6 turn tank coil so that the quiet spot is again picked up. This will make the frequency of the tank circuit the same as the oscillator and the two stages will be in harmony.

### PEAKING

Finally, the project is peaked by adjusting the turns of the RFC until the reading on the multimeter is a maximum. This

improves the output up to 50% by allowing the RFC to do its job as we have described in other articles.

Remove the short on the IC, fit the antenna and the bug will begin to produce a beep, when the probes are touched.

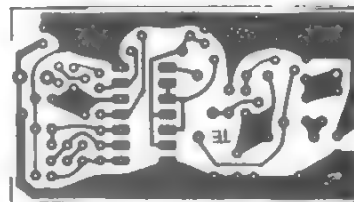
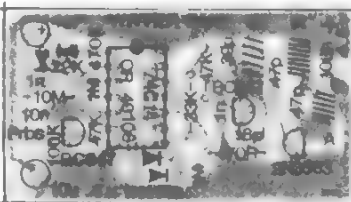
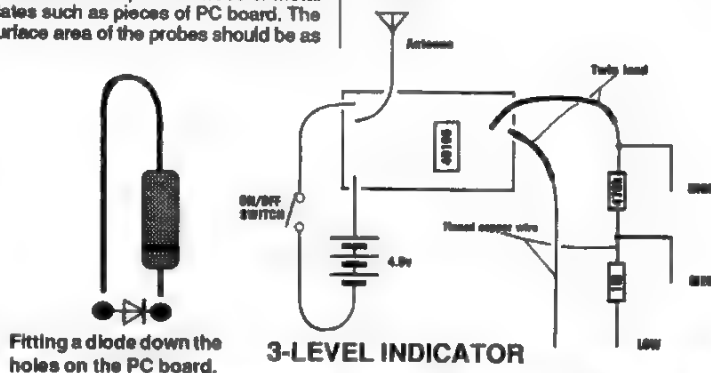
### MOUNTING

If you are going to use the bug in an open field or remote situation, it should be fitted into a small plastic box to protect it from moisture and dust etc.

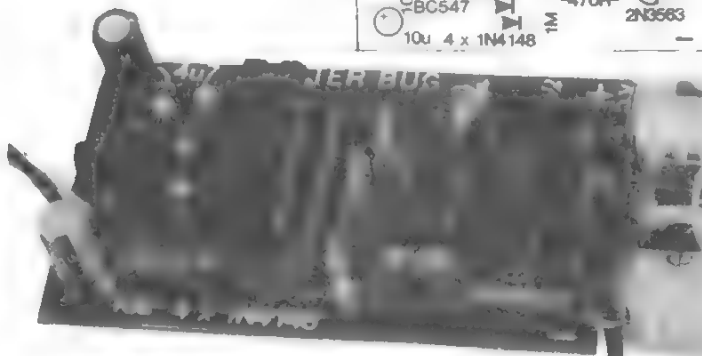
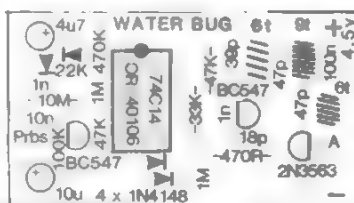
Bring the probe leads through a small hole and determine out how many levels of water you wish to detect. The probes can be nails in a piece of wood or metal plates such as pieces of PC board. The surface area of the probes should be as

large as possible so that the circuit will detect the first sign of water. Place the probes at the required levels, add the resistors to create the tones and the project is complete.

This project has already been used in many areas of protection and monitoring. It has enormous potential for use on farms as it is much cheaper than anything else on the market. All it requires is to be shown around and others will see its benefits. Do us a favour and promote it. In doing so, you will help yourself and us. I want this bug to get the recognition and sales it deserves, so see what you can do.



Water Bug artwork and photo of completed board







**VOX = Voice Operated Switch**

**LED power meter required to peak the bug:**

PCB layout by Justin Vletz



**Note: DC voltages during beep mode**

1T for top board - small board

18 for bottom board - large board

note: 6 leadthroughs between PC boards

feedthroughs. Four feedthroughs are shown on the circuit diagram as 1, 2, 3 and 4 and the other two are positive and negative. Nearly all the components are surface mount, except the 2N 3563 RF transistor, a BC 547, the three coils, the 3v9 zener diode, the microphone and the mini trim pot.

As you know, surface mount components are fitted to the track side of a board. To help you work out exactly where each component is placed, we have provided two enlarged diagrams of the underside of the boards. We have also included enlargements of the overlay for each board to show where the normal components are fitted.

In addition, we have included a side view to show how the two boards are fitted together.

Range: about 500metres  
Current: .5mA while listening  
.8mA on beep  
10-12mA on transmit  
Supply: 4 x N cells  
Battery life: 300-400Hrs  
Frequency range 88-108MHz  
Vox sensitivity: turns on v  
speech at 5 metres

Before starting, the three things you must invest in are a pair of fine tweezers, a length of fine solder and a soldering iron with a fine tip.

We use a pencil soldering iron with a temperature controlled tip, but until they are available at a reasonable price, I suggest you fit a very fine tip to your present soldering iron.

The VOX V is built on two PC boards that fit back-to-back with six

The first component to fit is the IC. Pin 1 for the chip has been marked on the enlarged diagram and this corresponds to the slight depression at one end of the chip. Make sure the pins line-up before soldering the diagonally opposite pin. Then solder the rest of the pins, quickly and cleanly without overheating the chip. Solder a few pins then wait a while to let the chip cool down.

Next fit the resistors. They are clearly marked with numbers and to help you with the values we have provided a list:

#### SURFACE MOUNT RESISTOR VALUES:

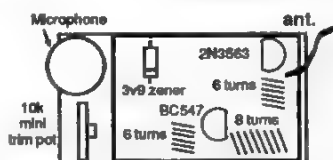
470R marked as 471 on chip  
4k7 marked as 472 on chip  
10k marked as 103 on chip  
22k marked as 223 on chip  
39k marked as 393 on chip  
47k marked as 473 on chip  
470k marked as 474 on chip  
1M marked as 105 on chip  
2M2 marked as 225 on chip

The peaking of the bug is carried out exactly the same as the VOX MkIV and will not be repeated here. Refer to the



black line

The surface-mount capacitors come in a strip with a black line at one end as shown in the diagram above.



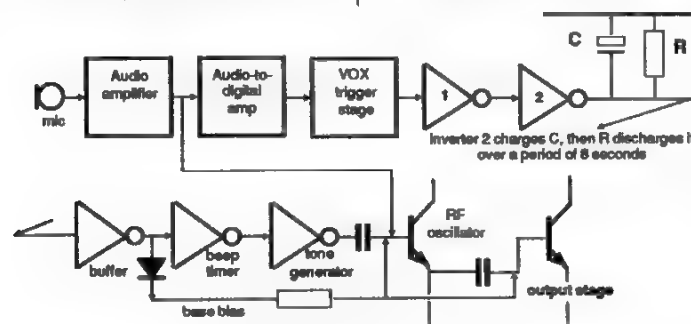
The two boards fit together like this, with the surface mount parts as shown:



Remember: ALL the components for the small board fit on the track-side. All the components for the large board fit on the track-side, except the microphone and 10k mini trim pot.

#### PARTS LIST

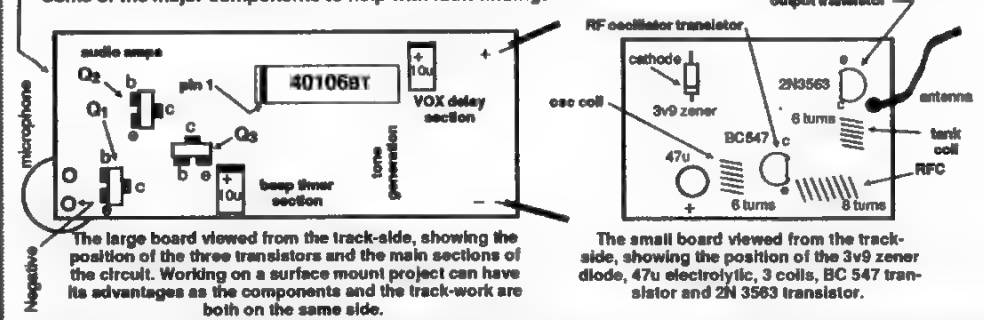
- 1 - 470R ALL surface-mount
- 1 - 4k7 1 - 47k
- 4 - 10k 1 - 470k
- 2 - 22k 4 - 1M
- 1 - 10M 1 - 2M2
- 1 - 10k mini trim pot
- 2 - 10p ceramics surface-mount
- 3 - 47p ceramics " "
- 3 - 1n ceramics " "
- 2 - 10n ceramic " "
- 3 - 22n ceramics " "
- 1 - 47n ceramic " "
- 2 - 10u 16v tantalums " "
- 1 - 47u 16v electrolytic PC mount
- 3 - BC 848 surface mount transistors Marked as "1k"
- 1 - BC 547 transistor
- 1 - 2N 3563 transistor
- 8 - BAS16 surface-mount diodes Marked as "A6s"
- 1 - 3v9 zener diode 400mW
- 1 - HEF 40106BT surface-mount hex Schmitt trigger IC
- 1 - electret microphone insert
- 2 - 6turn .5mm wire 3mm dia enamel
- 1 - 8turn .5mm wire 3mm dia enamel
- 1 - spdt mini slide switch
- 1 - 15cm tinned copper wire for feedthroughs
- 1 - 50cm fine solder
- 4 - 'N' cells
- 1 - 175cm antenna wire
- 2 - VOX MkV PC boards (one large, one small)
- 1 - LED Power meter kit (for peaking) available for \$1.10 extra.



BLOCK DIAGRAM OF VOX MkV

10k mini pot under

Some of the major components to help with fault-finding:



The large board viewed from the track-side, showing the position of the three transistors and the main sections of the circuit. Working on a surface mount project can have its advantages as the components and the track-work are both on the same side.

The small board viewed from the track-side, showing the position of the 3v9 zener diode, 47u electrolytic, 3 coils, BC 547 transistor and 2N 3563 transistor.

VOXIV article in Learning Electronics book 2 for fault finding and other related information.

#### PARTS IDENTIFICATION

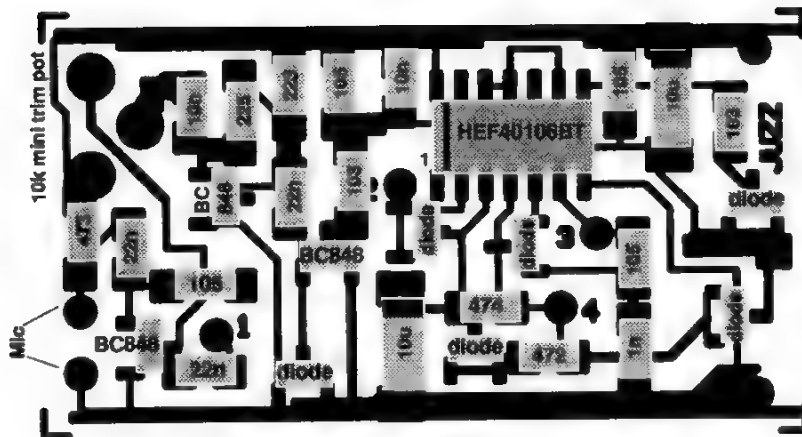
The only area we will talk about is the

Identification of the surface-mount components.

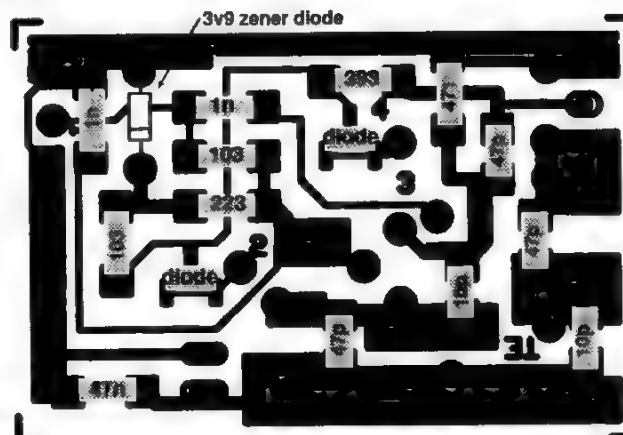
The transistors and diodes look similar as they are in the same type of package. But there are only three transistors and

8 diodes. You will find the letters "1K" or similar letters on the transistor package while the letters "A6" appear on the diode case. These letters may vary from one batch of components to another so





These diagrams are 250% enlargements of the board. You will get quite a shock when you get your kit and see how small the board is. This project will highlight the inadequacies of your old-style soldering iron. Be warned. Don't build it unless you are up to the demands of surface mount.



don't worry too much.

The resistors are all easily identified as they carry a three digit code.

The overlay on P81 identifies each of the resistors according to this 3-digit code and the overlay on P60 identifies the resistors according to the circuit diagram.

The only components that are not identified in any way are the chip capacitors. That's why we have placed them in a strip with a black band at one end according to the diagram at the top of page 59.

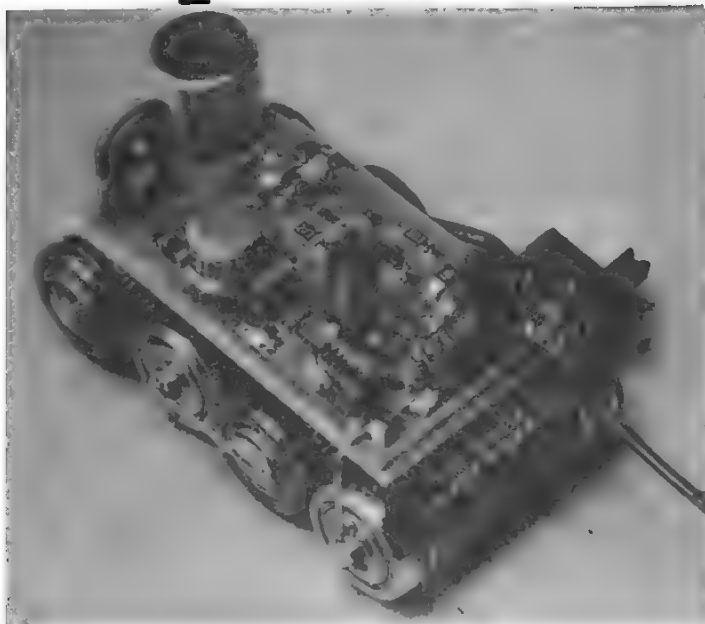
The size of the chip has nothing to do with the value of capacitance so remove the chips one-at-a-time and do not remove them until they are required.

Now, to the job of assembly.

#### ASSEMBLY

Pin number 1 for the surface-mount IC is identified by the white line across one end. The diagram in the middle of page 60 shows how the IC is placed on the board and the position of pin 1. Firstly solder the pins at opposite corners, making sure the rest of the pins are correctly positioned on the pads. Solder the rest of the pins. Next fit the two 10u tantalum capacitors.

Enlargements of the two boards showing the position of the surface-mount components with the resistor values according to the 3-digit code.



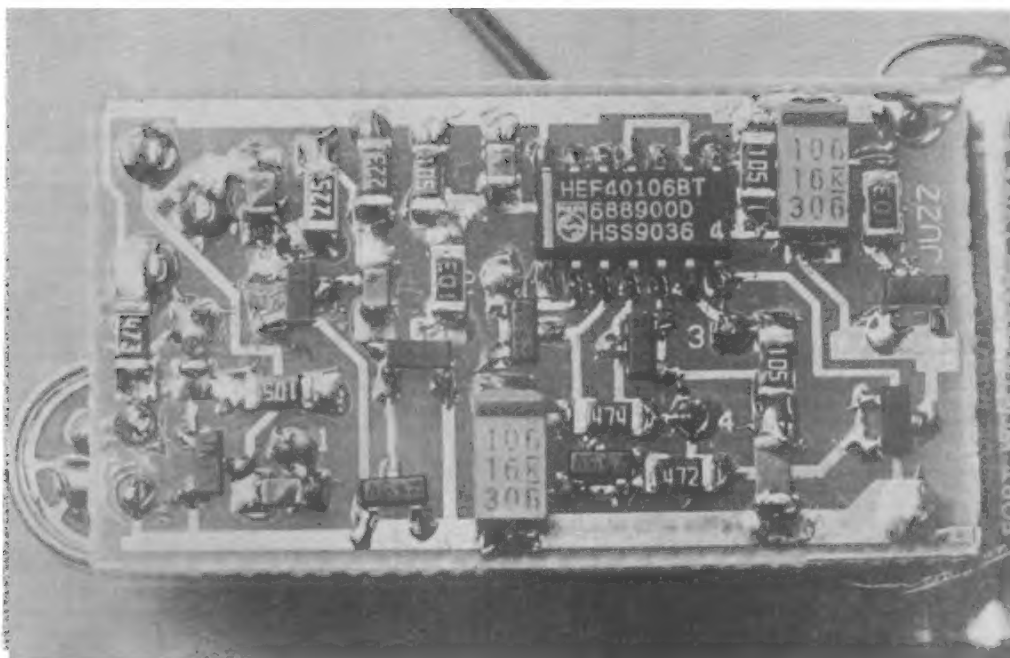
The positive end of the electrolytic has a red or brown line and a chamfer at one end and this is soldered to the board as shown in the diagram. The overlay on the board indicates the positive end with a white rectangle.

You must have a temperature controlled soldering iron or at least a small wattage iron when soldering the transistor and diodes to prevent them being damaged.

#### HEATSHRINKING

The completed project can be protected from damage by fitting heatshrink material over the two boards and heating with a candle, cigarette lighter or hot-air gun.

Photo of the completed project showing the mounting of the 47u electrolytic, 2 transistors, 3 coils and antenna lead as well as the positive and negative leads of the battery. You will notice the on/off switch has been soldered directly to the 'N' cells as this is the best place.



A hole is then cut in the heatshrink for the microphone and sensitivity pot. To prevent the heatshrink from damaging the two coils near the edge of the board, a small piece of PC board or plastic should be fitted beside the edge of the board so that the coils are not squashed as the heatshrink contracts during shrinking.

Fit the four 'N' cells and the project is ready to go into operation. Don't forget to add the mini slide switch to the end of the cells so that the project can be turned off when not required.

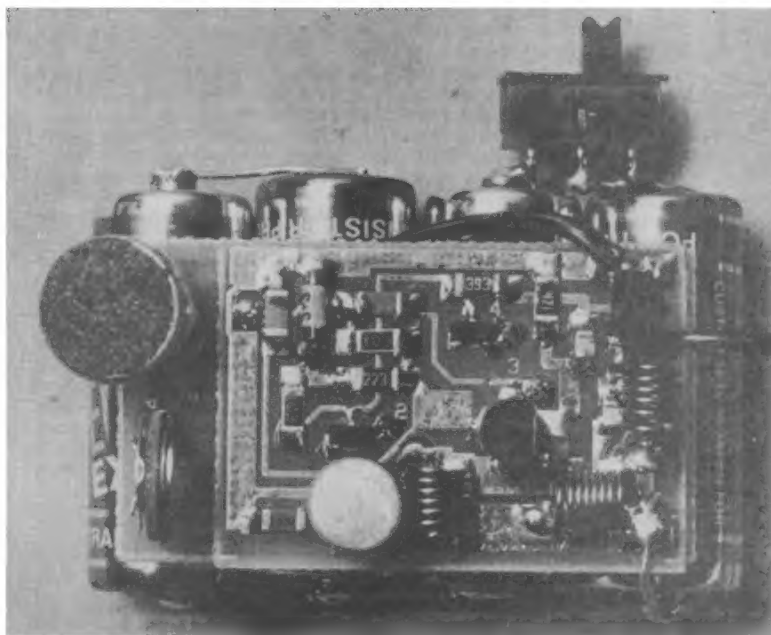
Only you will know and appreciate the work and skill that went into putting it all together. Try it out and see how fantastic it performs.

**These large photos show you exactly where the parts are fitted to the board. Don't forget, the photos are 2½ times larger than actual size so don't think the project will be a breeze.**

The most difficult component to solder in place will be the electrolytic as you have to get under it with the iron to solder the short leads.

You can also see how the feed-throughs are soldered from one board to the other.

This photo clearly shows the identification on the transistors (1k in our case) as compared to the diodes (A6S in our case). These numbers may be different in your kit so make sure you know which is which before starting. The IC has a chamfer along the bottom edge of the chip. This gives pin 1 identification at the left hand end of the chip.

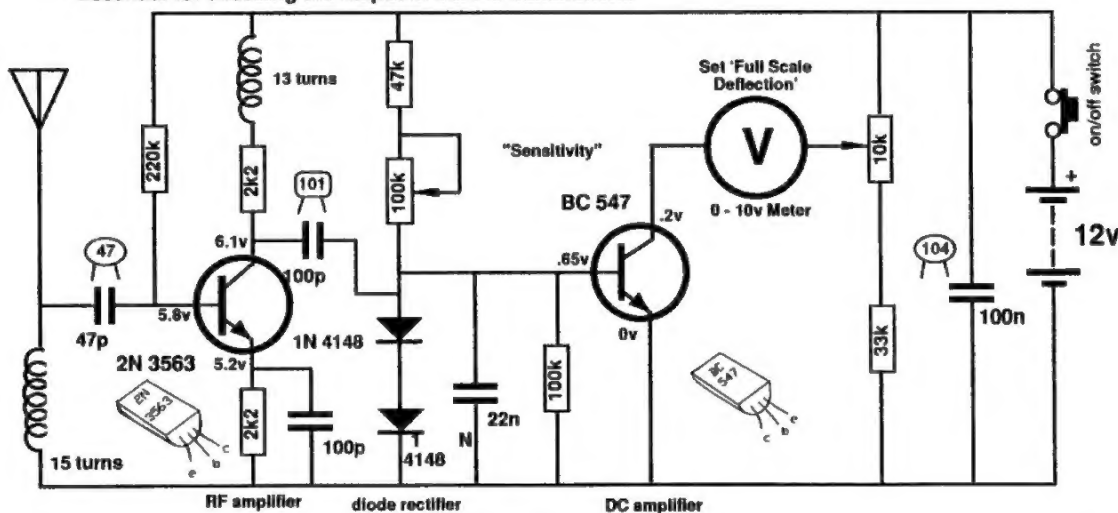


# THE FIELD STRENGTH METER

## Parts & PC Board

See the end of the article for our Field Strength Meter MkII

Essential for checking the output of our FM transmitters.



## FIELD STRENGTH METER CIRCUIT

This Field Strength Meter has been specially designed for our FM bugs. It is capable of detecting very low power transmitters and will assist enormously in peaking the Amoeba, Ultima, Vox IV & V and checking the output of the other bugs too.

Up to now, field strength meters have only been able to detect transmitters with an output of 100 milliwatts or higher, and for an output such as this, a simple circuit such as a meter and a coil is sufficient. But when it comes to a low power device, a simple circuit, with no amplification, is not suitable.

We spent more than 5 days building all the circuits we could find, that purported to be suitable for low-power transmitters, hoping that one of them would work.

Unfortunately none came anywhere near good enough so we had to design our own.

The circuit we came up with is shown above and it incorporates an RF amplifier, diode rectification, and a DC amplifier so that a movement from a multimeter (a movement is the 'meter' part of a multimeter) could be used as the readout. The heart of the design is a pair of diodes that are partially turned on via a resistor (the 100k sensitivity control) and this overcomes some of the .6v threshold of a diode.

You may not think .6v is very much but when you are talking in millivolt terms, it is 600 millivolts. The signal we are attempting to pick up produces one or two milli-volts on the receiving antenna and if you need 600 millivolts to turn a diode ON, the field strength meter becomes very insensitive.

Our design overcomes this problem and produces a reading up to 10cm from a bug. This means you can adjust and peak a bug with the antenna fitted and get an accurate indication of the power it is producing.

Up to now you have had to rely on the "LED Power Meter" as described in the Amoeba and Ultima articles and although it gives a good indication of the RF energy, it does not take into account the loading effect of the antenna.

The antenna loads the output stage of any transmitter and when you have a low power device such as ours, the antenna tends to detune the frequency slightly so that a slight re-peaking is necessary if you want to get maximum performance. The field strength meter will allow you to do this and get back the extra performance you may have lost.

## HOW THE CIRCUIT WORKS

The circuit consists basically of an RF amplifier, diode rectifier and a DC

## PARTS LIST

- 2 - 2k2
- 1 - 33k
- 1 - 47k
- 1 - 100k
- 1 - 220k
- 1 - 47p ceramic
- 2 - 100p ceramics (101)
- 1 - 22n ceramic (223)
- 1 - 100n ceramic (104)
- 1 - 10k mini trim pot
- 1 - 100k mini trim pot
- 1 - BC 547 transistor
- 1 - 2N 3563 RF transistor
- 2 - 1N 4148 diodes
- 1 - 13 enamelled wire 3mm dia coil
- 1 - 15 enamelled wire 3mm dia coil
- 1 - 12v lighter battery
- 1 - 25cm enamelled wire
- 1 - SPDT mini slide switch
- 2 - paper clips
- 1 - FIELD STRENGTH METER PC BOARD
- 1 - multimeter (0-10v range)

amplifier. The first feature that may be new to you is the inductor in the antenna circuit. You may think it produces a short-circuit between the antenna and earth but the inductance of the 15 turn coil creates a voltage across it when the



antenna picks up a signal. This voltage is fed to the base of the first transistor via a 47p capacitor and since the transistor is turned on via a 220k resistor, any signal from the 47p will be amplified by the transistor.

The RF amplifier has been designed to only have a gain at high frequencies. In our case this is at about 100MHz to 300MHz. The 300MHz is the upper limit due to the response of the RF transistor and the lower frequency is governed by the 100p bypass capacitor on the emitter.

It's impedance at 100MHz is 16 ohms and this gives the stage a gain of about 12. At 10MHz the reactance of the capacitor is 160 ohms and the gain of the stage drops to about 2.

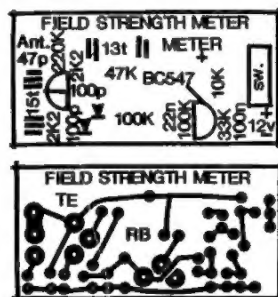
This prevents low frequencies from being amplified and up-setting the reading.

By increasing the value of the emitter bypass capacitor, the gain of the stage will be increased but this is not desirable as it may cause excessive gain in which the front end self-oscillates.

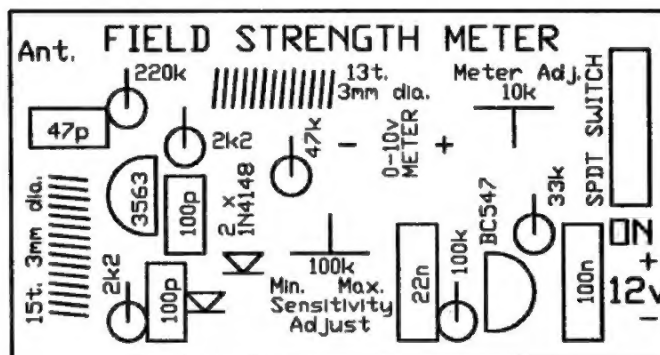
The inductor in the collector circuit separates the output signal from the power rail and increases the output amplitude slightly.

The low value coupling capacitor (100p) between the RF stage and diode pair is sufficient to transfer the energy as, don't forget, we are dealing with very high frequencies. The two diodes in the diode stage simply work as a rectifier and are partially forward biased via a 47k and 100k 'sensitivity' control from the positive rail. But they are not turned on fully due to the base emitter junction of the DC amplifier transistor only allowing .6v to appear across them.

When a signal is passed into the diode pair, the negative excursions reduce the voltage across them and this begins to turn off the DC amplifier transistor and thus the needle on the meter drops. It requires about 300mV signal to start the process and with a gain of about 12 on the RF transistor, we need about 30



The circuit is attached to an ordinary multimeter set to 12v scale. The needle "dips" when RF is detected.



The new CAD board shown 250% larger than normal.

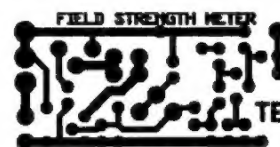
millivolts developed on the antenna circuit to start the detecting process.

The makes the Field Strength Meter only sensitive to nearby signals and prevents weaker signals from upsetting the reading.

The 10k pot connected to one end of the voltmeter sets the full-scale deflection for a 0-10v range on the multimeter.

The circuit consumes about 3.5mA and with a lighter battery (50mAHr cells) the circuit will operate for more than 12 hours. A switch is provided to conserve the battery when not required and the board attaches to any multimeter via leads and paper clips that have been bent to suit the banana sockets on the meter.

Any old meter will do and it can have a sensitivity from 1k ohms per volt to 50k ohms per volt. The range we used in our prototype is 10v DC on a 30k ohms per volt meter however 12v, 15v or even 25v scale will be ok and the 25v range simply means the needle will not deflect as much, for the same RF detected.



FSM artwork

You can even use an old, broken, multimeter providing the movement is not damaged. We have about 5 of these field strength meters at work, one for each worker, as everyone needs one to peak the devices we are making.

We turned 5 broken multimeters into active service. It's one good way of using up damaged equipment. It's amazing how the staff can blow up things, with the ohms range not working and the millamp range burnt out.

I remember one firm had the same problem. They made all the staff spend every Friday afternoon repairing the test equipment - but with the tight economics of today, we couldn't afford the luxury of providing half a day's holiday like this each week.

## CONSTRUCTION

All the components, including the 12volt lighter battery and switch, mount on the PC board. The legend on the board shows where each part is placed and we have found it important to avoid over-heating the diodes and transistors as they lose their peak performance and cause the circuit to become very insensitive. Follow the overlay on the PC board to see where everything is placed. The coils are pre-wound in the kit and are wound on a 3mm diameter Philips screwdriver (if you are making your own) and the wire size is not critical as they simply form a broad-band trap.

The new artwork for the project is a CAD board and is shown above. As soon as the old-style boards have been used up we will be supplying the new board.

The antenna wire is enamelled to prevent it touching the active components of the bug you are testing.

We needn't say any more about construction as you will obviously know how to put the kit together.

#### SETTING UP

Solder the paper clips to the board as shown in the photos and bend them to suit the sockets on the multimeter. Turn the "sensitivity" control (100k pot) to minimum resistance and switch the circuit ON. Turn the "Set full scale deflection" pot (10k) to give full deflection on the meter. Now turn the sensitivity pot until the needle just starts to "dip."

At this point the circuit is the most sensitive as the DC amplifier transistor is just turned on and any signal appearing on the diodes will reduce the voltage appearing on the top of them and turn the transistor off. The Field Strength Meter is now ready for use.

#### USING THE FIELD STRENGTH METER

This project will help you get the best out of any transmitter. It will give an accurate readout because it does not connect to the transmitter but registers the strength of the field AT A DISTANCE.

The way it is used is to set up the antenna of the Field Strength Meter in the same plane as the transmitting antenna (to get the best pick-up) and at a distance that just causes the needle on the meter to deflect.

The meter is wired as a "DIP" meter and the needle deflects towards zero as the field strength increases. Place the bug to be peaked on the test bench, with the antenna out-stretched and bring the receiving antenna so that the needle just starts to dip.

Peak the circuit a small amount and take your hands away so that they don't upset the reading, and watch the needle. As the output increases, the needle dips further. By maintaining the exact same distance between bug and meter, you can compare one bug with another.

It's the fastest way of determining the output without doing a "field test."

#### IF IT DOESN'T WORK

As with all our projects, they work because we have actually built them and checked their performance. If yours doesn't work, the first thing to do is check the value of the components against the overlay on the board.

Two components in the wrong place can make a huge difference and a circuit like this is fairly critical as the biasing must be correct.

Secondly, make sure all the parts are fitted and nothing has been missed. Also make sure all the parts have been soldered neatly and cleanly.

We still get projects sent to us for repair where one or more leads have not been soldered and obviously the project could never work.

Next you can make a few voltage readings. Although they don't tell you too much, it is a fast way of determining if a stage has the correct DC conditions. The voltages are:

RF Stage:

Collector: 6.1v

Base: 5.8v

Emitter: 5.2v

DC stage:

Collector: 2v

Base: .65v

Emitter: 0v

If these check out ok, you should make a few further DC tests. If the meter swings full scale at power-up, you should short between base and emitter of the BC 547 to see the needle falls to zero. This will show the transistor is working ok. If not, the transistor may be shorted.

Next remove the 47k on the diode pair. This will also cause the needle to move down-scale and show the biasing network is working. It is more difficult to test the RF stage and merely probing around the stage with a meter or CRO, will pick up hum and cause the needle to deflect.

Of course we have assumed you have bought a kit and PC board for the project. The frequency of operation of this circuit makes it important that it is built on the correct PC board.

We cannot guarantee "breadboard" jobs or circuits made with your own components as so many variables creep in. Things like different markings on capacitors, different RF transistors or signal diodes could make the difference between success and failure.

If you know what you are doing, that's fine - you can use your own components. But if you intend to learn from our projects, don't take any chances. It's cheaper in the long run to get all the projects in kit form and build them exact-

ly as specified.

If you get really stuck, don't hesitate to buy another kit and start again. You can come back to the faulty one later. This project is so important that we don't want you to miss out. With a field strength meter you can carry out experiments that would take a chapter of a book to explain. Here's one:

#### EXPERIMENTING

Take the Voyager project and connect 30cm of tinned copper wire to the antenna point on the PC board. Hold the Field Strength Meter in your hand (keep away from the actual circuit by holding the multimeter) and bring the receiving antenna near the Voyager antenna, without touching it. As you move up and down the Voyager antenna, watch the needle.

It will show that energy is not radiated uniformly from the antenna but has a maximum and minimum value. It is for you to see where these occur. Measure the length of the antenna and plot the results. Cut 2cm off the antenna and repeat the tests. Fit a 175cm antenna to the bug and repeat the tests.

This will give you a good understanding of the phenomenon of electromagnetic radiation.

There are lots of other things you can test with this project including our latest Pen Bug with active antenna and I am sure you will find it essential for RF work.

The Field Strength Meter MkII will be presented in one of our next books and will have the advantage of a tuned front end and 3-LED readout. This will enable you to not only peak the transmitter but also find the frequency on which it is operating.

But don't put off building this project as you will need both of them as they have different capabilities. And you also need the LED Power Meter. Test equipment is very important when working with RF so don't put it off any longer, start building now.

A close-up of the board showing the two mini trim pots and 12v lighter battery.

